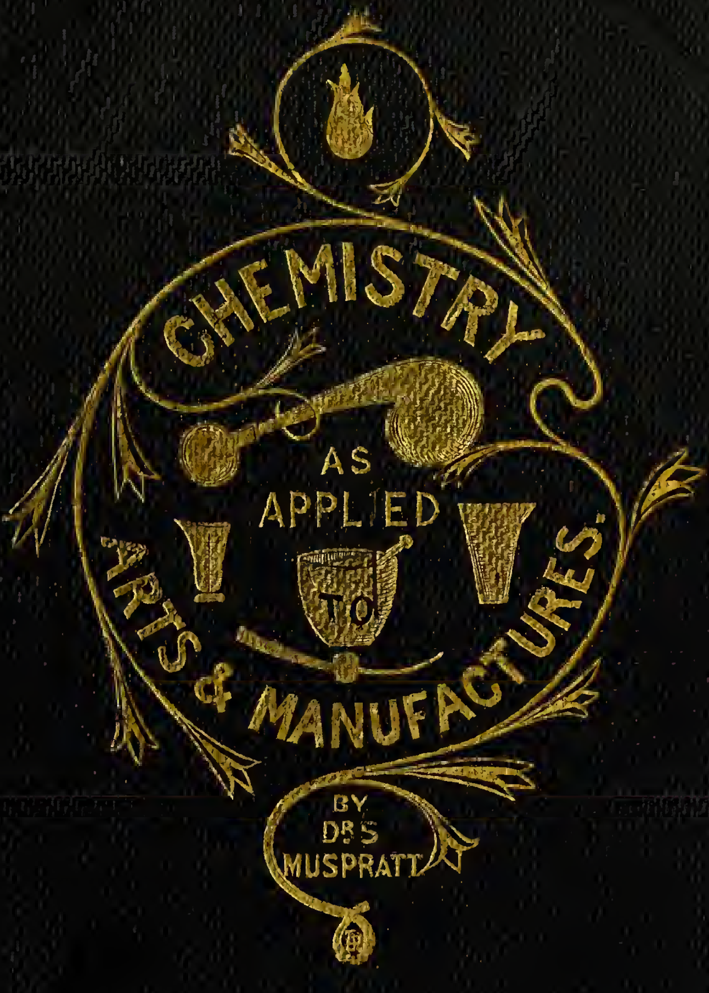

CHEMISTRY AS APPLIED TO ARTS & MANUFACTURES.

BY
DR S
MUSPRATT

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Chemistry

Theoretical, Practical & Analytical

AS APPLIED AND RELATING TO

The Arts and Manufactures

BY

DR. SHERIDAN MUSPRATT, F.R.S.E. M.R.I.A. F.G.S.

VOL. II

William Mackenzie.
Glasgow. Edinburgh. London. and New-York.

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PROFESSOR CHEVREUL.

PROFESSOR OF APPLIED CHEMISTRY AT THE GOBELIN MANUFACTORIES, AND EXAMINER IN THE ÉCOLE POLYTECHNIQUE.

E. Chevreul

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BARON JUSTUS LIEBIG M.D. F.R.S. &c.

PROFESSOR IN THE UNIVERSITY OF MUNICH

Justus von Liebig

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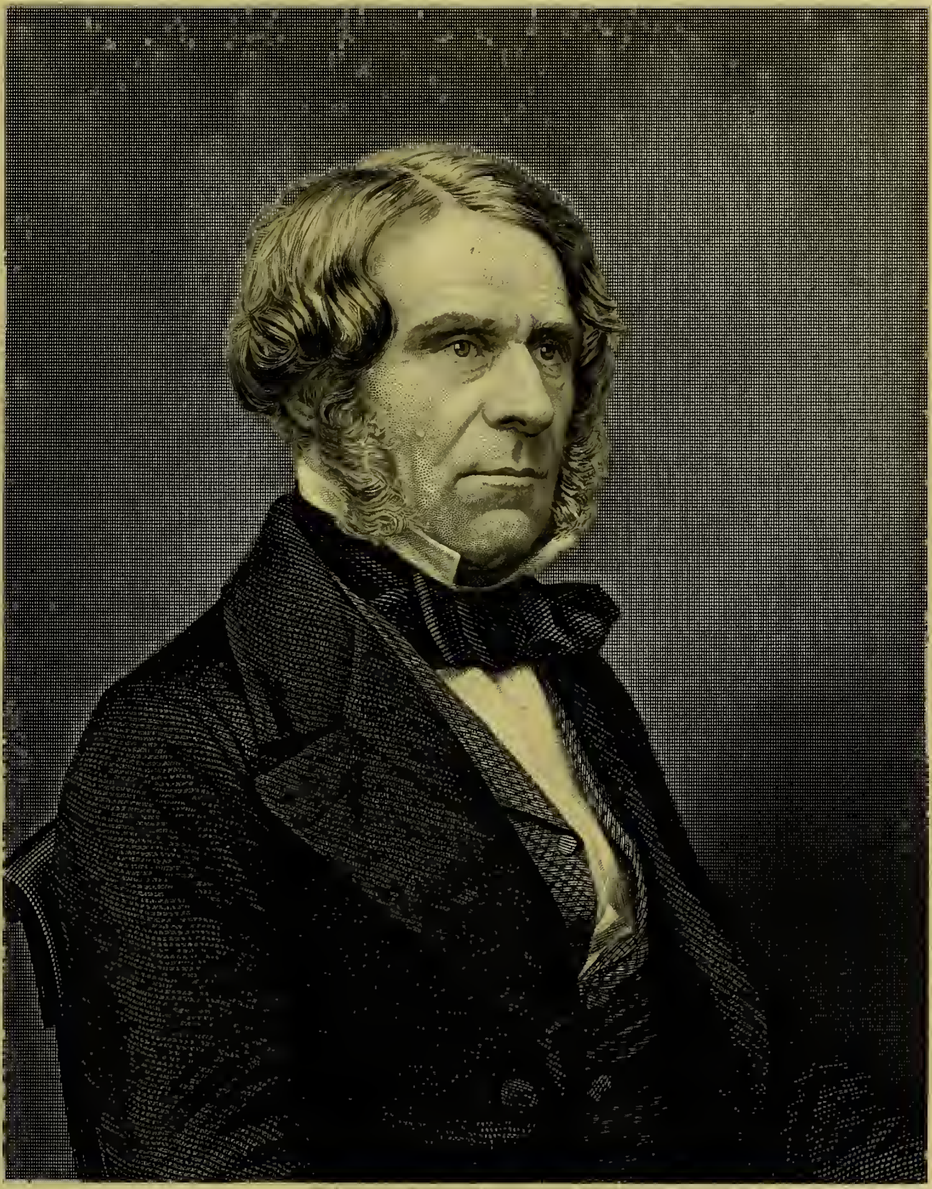

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covery of new materials for its production, and has opened new channels to commerce.

When the soda prepared from common salt was first introduced into the soap manufacture, for making yellow soap, the fabricators purchased it in the form of *black ash* or *ball soda.* This, at that time designated also British barilla, is the residue of the calcination, in a reverberatory furnace, of a mixture of sulphate of soda, chalk or broken limestone, and small coal; and when lixiviated with cold or luke-warm water, affords a solution of carbonate of soda, containing also a small quantity of caustic soda and sulphide of sodium, together with a portion of undecomposed chloride of sodium and sulphate of soda. The alkaline carbonates now used by soap manufacturers, are white ash or soda ash. This is obtained by lixiviating the above-mentioned black ash in water, drawing the solution from the insoluble matters, and evaporating to dryness. The residue thus obtained may be used for making lie; but, as it usually contains some sulphide, which, in the production of white soap, is a source of inconvenience, it is necessary for some purposes to calcine this residue at a moderate heat, whereby nearly the whole of the alkaline sulphide becomes oxidized and converted into sulphate.

This ash contains carbonate of soda sometimes to the amount of ninety-five or ninety-six per cent. It is, however, essentially necessary in the production of soap, that the alkali should be rendered caustic—that is, set free from combination by the removal of carbonic acid; as, if it be in chemical union with any other body, it has no decomposing power over the oils or fats. Even if combined with the weakest acids, saponification will not ensue; and the greatest care should, therefore, be exercised in this preliminary process—the preparation of the lies. The process for causticizing is the same in principle for the preparation both of soda and potassa lies. It depends upon the greater affinity of lime than of soda or potassa for carbonic acid, and the decomposition is one of the most simple, thus—

$$\underbrace{\mathrm{Na\,O\,CO_2}}_{\text{Carbonate of soda.}} + \underbrace{\mathrm{Ca\,O}}_{\text{Lime.}} = \underbrace{\mathrm{Ca\,O\,CO_2}}_{\text{Carbonate of lime.}} + \underbrace{\mathrm{Na\,O}}_{\text{Soda.}}$$

The proportions of soda ash and lime employed vary according to the degree of strength of the soda; similarly with regard to the potassa salt. It is, however, always an advantage to have an excess of lime over the alkaline carbonate, as in the contrary case any undecomposed carbonate is totally lost.

A fact deserving of mention in treating of the preparation of lies is, that in the process of causticizing by means of lime, a portion of the soda appears to enter into some form of combination very difficultly soluble. Mr. KYNASTON, a student of the Editor's, lately examining the calcareous deposit, found it to contain, after being well washed, soda to the amount of five or six per cent. When the deposit, after being dried, is heated to a temperature insufficient to expel carbonic acid, and, after being allowed to cool, is again drenched with water, caustic soda is then removed with great ease, and the deposit may be almost completely deprived of soda. Taking these facts into consideration, the Editor is of opinion that it would well repay the soap manufacturer to collect the lime deposit, and, after thorough desiccation by exposure to the air, to submit it to heat until the carbonic acid is expelled. The lime now again become caustic, may be used advantageously in the preparation of fresh lie, and the process may be repeated until the deposit becomes highly charged with the impurities of the ash, when fresh lime may again be used for a new process.

Another of those progressive steps manufacturers frequently take, leading to the simplification of operations which previously had been tedious, laborious, and wasteful, has been taken in the soda trade, the especial benefits of which are to be derived particularly by the soap-maker and the public generally. This intellectual advancement consists in preparing *directly* the caustic alkali, by the use of which the soap-maker at once dispenses with a considerable plant outlay, economizes space, expedites the operations of his trade, and effects no little amount of saving in labor alone, compared with the present general practice. Besides the foregoing immediate and apparent advantages resulting in favor of the soap-maker, from the employment of caustic soda prepared *directly*, there are others of much greater importance—namely, the economy of alkali, and the readiness with which soap can be made by the use of lies, the strengths of which are immediately under control, and which cannot be obtained economically on the present causticising system to which soda ash is submitted, unless at considerable trouble; and even then the lies are not pure, owing to the circumstance that strong caustic alkaline solutions divest carbonate of lime of a portion of its carbonic acid.

The article in question, being in the solid state, is most convenient for transit and storage. It is now prepared largely in some alkali works; MUSPRATT BROTHERS, and HUNTLEY, of Flint, North Wales, manufacture it to a very considerable extent, and the trade is likely to be greatly increased; and the Editor is convinced that its employment would be much more economical to the soap manufacturers than the present method of preparation. It requires simply to be dissolved in a given quantity of water, to produce lies ready for use, and of any required strength. In America it is now largely employed for this purpose, but in England rarely, if at all. Its introduction, though a great advantage to the soap producers themselves, will probably be a matter of as much difficulty as was that of the introduction of the so-called artificial soda, at least as regards the English manufacturer. The method of preparation of this caustic soda will be fully described in a subsequent article. It is of such a nature that it cannot be economically or, indeed, conveniently applied, except where artificial soda is produced to a considerable extent. Being perfectly free from sulphide of sodium, it is especially applicable to the production of white soaps.

Testing the Lie.—That the soap-boiler may be in a position to carry out his method accurately, and to proceed with safety, it is necessary during the lixiviation in the ash tubs, and whilst boiling the fat, that he should be able at any moment to ascertain correctly the strength of the lies. For this purpose specific gravity bulbs, or the *hydrometer*, is used. In this country Twaddell's hydrometer is most commonly employed.

The indications of such an instrument are in no kind of connection with the chemical nature of the fluid; and as the graduation is perfectly arbitrary, nothing more can be established by its application than a comparison of the densities of different liquids. As, however, a correspondence has already been established between the degrees of the hydrometer and the specific gravities, and it is also known what proportions of potassa and soda correspond to the specific gravity of different solutions, the hydrometer may be used as a means of ascertaining the amount of alkali present. The degree indicated by Twaddell's hydrometer, multiplied by five and added to one thousand, expresses the specific gravity of the fluid. A lie testing 27·50 Twaddell, for instance, has a density equal to 1·138, which is equivalent to 15 per cent. of potassa or 12·8 per cent. of soda, always supposing the lie to contain no other matters or salts which might also affect the specific gravity. This, however, is never the case with soap-boilers' lie, so that the indications are only approximations with reference to the amount of alkali, or even may be altogether fallacious. Still they are useful in a variety of ways, and are, indeed, indispensable. The practitioner is able with this instrument to follow the diminishing strength of the liquid flowing from the ash tubs or vats, and to form a just estimate of its value, when, at the same time, a test with acid proves the absence of carbonic acid. But even in the process of soap-boiling itself, the test of the lie afforded by the hydrometer, combined with the personal experience of the workman, is a clue by which he is enabled to judge whether the proper strength has been attained; knowing as he does what degree the hydrometer ought to indicate from any particular soda or potassa lie for any particular purpose. The more or less caustic taste of a lie is also a test much depended on by many soap-boilers.

SAPONIFICATION.—Oils and fats themselves are neither soluble in water nor miscible with it; but nearly all are made so by union with alkali. The process of effecting this combination is termed *saponification*, and the compound produced is *soap*—hard soap when its base is soda, but more or less soft when potassa is the alkali present. The properties and composition of the different kinds of oil and fat, as well as their behavior under the influence of various reagents, have been fully discussed in a separate article. It is, however, necessary in considering the theory of saponification, again to notice the constitution of these bodies in its bearing upon their conversion into soap. The fixed oils, as well as the animal fats, are composed for the most part of certain proximate principles, of which stearin, margarin, and olein are the most abundant. Some oils, as for instance palm oil, have constituents peculiar to themselves; but as they are quite analogous to olein, and other bodies above-mentioned, in their chemical constitution, and consequently similar in their relation to alkalies, these will serve as examples.

In animal fats stearin is usually the most abundant constituent; margarin more especially characterizes the vegetal and human fats; olein is present in both, though varying in its nature in different kinds of oil.

Stearin, margarin, and olein, however, are not free uncombined bodies, but positive compounds, each of its respective acid with a base, termed *oxide of glyceryl*, the hydrate of which is glycerin. Thus, though the base is the same in all, the acid constituent in each of the three is peculiar. The acid in stearin is termed *stearic acid;* that in margarin, *margaric acid;* and that in olein, *oleic acid.* Stearin, margarin, and olein have, therefore, a saline constitution, and may be respectively regarded as a stearate, margarate, and oleate of oxide of glyceryl. When brought into contact with a free alkali, or a metallic oxide in presence of water, these fatty principles undergo decomposition; the alkali, or metallic oxide, being a more powerful base, seizes the oily acid, and a stearate, margarate, or oleate of potassa is formed, as the case may be. These latter compounds, when mixed with a solution of a more powerful acid, such as the mineral acids, or even of the stronger organic acids, as oxalic, tartaric acid, *et cetera*, are decomposed, a salt of the base with the acid employed being produced, while the oily acids are set free, and at the instant of separation combine with a certain proportion of water. The oxide of glyceryl, liberated from the fatty principle by the action of an alkaline solution, also at the moment of separation enters into combination with a definite proportion of water, the product being glycerin, which, owing to its sweet taste, and the source whence it is procured, was originally termed the sweet principle of oils. It will now be more easily understood that the oils or fats, or the principles of which they are composed, are themselves incapable of *direct* combination with the alkalies, or other bases; or, in other words, the mixture of a fat or oil with an alkali, does not occasion the formation of soap. On the addition of water, however, with which the base of the fatty principle may combine, saponification ensues immediately. Previously to the admirable investigation of CHEVREUL, to whom chemists are indebted for a knowledge of the composition of oils and fats, and their peculiar properties and behavior, the presence of water in the process of saponification was supposed to occasion a change proportional to its elements, converting the stearin, margarin, and olein into new bodies, which from their acquired acid properties were termed adipose or saponic acids; the peculiar unsaponifiable body glycerin being left behind as an incidental product. Hence, what are now known to be positive compounds of a fatty acid with the base of glycerin, were considered as altered in ultimate composition by the action of water and alkali. This view is now known to have been fallacious, and it has been conclusively demonstrated that the acids exist ready formed in the fats, and are separated from the base-oxide of glyceryl, in accordance with that law which determines the power of stronger bases over weaker ones.

Thus, therefore, when solution of potassa or soda is boiled with oils, the fatty acids are abstracted, and the eliminated oxide of glyceryl, uniting with water, forms glycerin. And thus it is explained why the fatty acids separated from oil, estimated together with the glycerin, always exceed the weight of the oil or fat submitted to decomposition—the excess being due to the water entering into combination both with the glyceryl base, and with the fatty acids. The following diagram will render the decomposition that ensues, when an oil is saponified, much more intelligible :—

Substances employed	Composition.	Products of decomposition.
Fats or oils, namely, stearate, margarate, oleate, *et cetera*, of oxide of glyceryl.	Stearic acid, Margaric acid, Oleic acid, + Oxide of glyceryl,	Stearate, margarate, and oleate of potassa or soda, that is, soap.
Potassa or soda, Water,		Hydrated oxide of glyceryl, that is, glycerin.

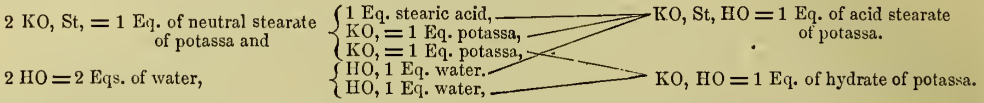
Soap, therefore, it will be observed, does not result from a direct union of the fatty matter with the alkali; a further proof of which is seen when the soap obtained as above is decomposed by the agency of a stronger acid. It will be found that the acid decomposing the soap, by seizing its alkaline base, leaves the fatty material in a totally different state to that in which it existed when originally added. It is now found to possess acid properties, and to unite much more readily with alkalies; or, in other words, to be more easily saponified. This latter property is accounted for from the fact that, being in an uncombined state, the acids have no base to overcome, as was the case in the first instance. In all saponifiable fats, the same reaction ensues, though the soap produced contains different acids, according to the kind of grease or fat employed. Thus, in the case of palm oil, the soap consists for the most part of *palmitate* of soda or potassa. When spermaceti is used, the soap produced consists of *cetylate* of potassa or soda, and instead of glycerin, an analogous body termed ethal is found in the mother-liquor. By far the greater majority of fats, however, yield when treated with alkalies, soaps containing only stearate, margarate, and oleate of potassa, if a soft soap, and of soda in the case of hard soaps. Resin, though employed in the manufacture of soap in the place of fixed oil or fat, is not to be considered analogous to a fat in its chemical constitution, or to be capable of forming with an alkali a proper soap by itself. Resin contains neither oxide of glyceryl nor oxide of cetyl, nor any equivalent for these substances, but is an indefinite mixture of three distinct bodies possessing well-marked acid properties; and hence named *sylvic*, *pinic*, and *colopholic* acids, each of which is capable of entering into combination with alkalies, and of readily dissolving in alkaline solutions, though totally insoluble in pure water.

For the complete saponification of fats or oils, an excess of alkali is requisite, and is so much the more willingly employed, as it can be removed again without difficulty. The production of soap is by no means a momentary process, nor can it be done with the same exactness or rapidity as the decomposition of an ordinary salt. On the contrary, the manufacture consists of a number of stages, and these occupy a considerable length of time from the first mixing of the fat with the alkali, when a sudden emulsion is produced, to the formation of soap ready for use, or even to that point when the whole of the alkali is saturated with fatty acid. Acid salts are first produced with the oily acids, and these hold the remainder of the fat in solution, or in a state of division, until it also is able to combine with alkali, and transform the acid into neutral salts, or into finished soap. This reaction may easily be observed, if the fat is boiled with one-half the required quantity of alkali; the whole of the oil is in such case dissolved, but the solution becomes turbid on cooling, and when water is added, and the mixture again boiled, unsaponified fat separates, showing that this had only been retained in the fluid by the stearate or margarate of the alkali that had been formed.

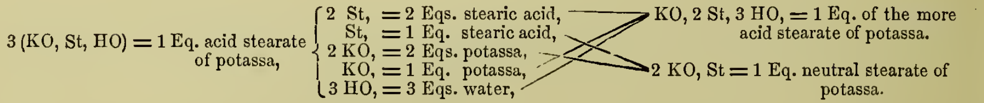
HARD AND SOFT SOAP.—Soaps are divided into two classes, differing from each other in the material from which they are produced, and are distinguished by the names *hard* and *soft soap*. Hard soaps are made from fats, or vegetal fat oils, and soda; for soft soaps, the oleaginous material is usually a fish oil or vegetal drying oil, and the alkali, potassa. Hard soaps may, however, be made with potassa, provided a solid fat be employed; but soda soaps are invariably harder than potassa soaps, the unctuous material being the same. The hard soaps of animal fats are either white or marbled, and are particularly applicable for washing the finer articles of dress, the soft soaps being more caustic than the solid soda soaps. Of the hard soaps of commerce those made with oils, with the exception of palm-oil, are mixtures of margarate and oleate, with only a small proportion of stearate of soda; those made with animal fats are mixtures of stearate, margarate, and oleate of soda. On the continent, and wherever wood is abundant, potassa is frequently introduced in admixture with soda in the production of hard soaps.

PROPERTIES OF SOAPS.—Potassa and soda soaps are readily soluble in hot water and alcohol; the addition of a quantity of water to the aqueous solution produces a precipitation, the neutral salts of stearic and margaric acids decomposing into free alkali, which remains in solution, and acid stearate and margarate of alkali, which precipitates in the form of pearly, crystalline scales. Potassa soaps are more soluble in water than those containing soda. Stearate of soda may be regarded as the type of hard soaps; in contact with ten times as much water it suffers no striking change, while stearate of potassa under the same circumstances forms a thick paste, or a viscid solution. In these respects the margarates of potassa and soda closely resemble the corresponding stearates. Oleate of soda is soluble in ten parts of water, and oleate of potassa in four parts. The latter forms a jelly with two parts, and possesses such a strong affinity for water, that one hundred parts absorb one hundred and sixty-two when exposed to a humid atmosphere. It follows, therefore, that soaps are soft in proportion to the oleates, and hard in proportion to the stearates and margarates they contain; so that the softness or hardness of soap is not solely dependent upon the base that is employed.

Soap of Commerce—that is, stearate, margarate, or oleate of alkali—is never dissolved by cold water without decomposition. The neutral salts are resolved into alkali, which dissolves, and into an acid salt, which is precipitated. The same decomposition occurs when hot solutions of soap—particularly of dilute—are cooled. According to CHEVREUL, who particularly investigated this decomposition in the case of stearate of potassa, when a solution of this neutral salt—2 KO, St—is cooled, one-fourth of its potassa remains in solution, and a mixture of neutral with acid stearate of potassa is separated. If the same salt is dissolved in five thousand parts of cold water, the acid stearate—KO, St—is alone precipitated in the form of pearly scales, and half of the potassa remains in solution according to the subjoined equations:—


2 KO, St, = 1 Eq. of neutral stearate of potassa and
2 HO = 2 Eqs. of water,
1 Eq. stearic acid,
KO, = 1 Eq. potassa,
KO, = 1 Eq. potassa,
HO, 1 Eq. water.
HO, 1 Eq. water,
KO, St, HO = 1 Eq. of acid stearate of potassa.
KO, HO = 1 Eq. of hydrate of potassa.

Acid stearate of potassa, after being separated from the liquid as above, and treated with a thousand parts of *hot* water, is again decomposed into neutral stearate of potassa, and a still more acid stearate, as follows:—


3 (KO, St, HO) = 1 Eq. acid stearate of potassa,
2 St, = 2 Eqs. stearic acid,
St, = 1 Eq. stearic acid,
2 KO, = 2 Eqs. potassa,
KO, = 1 Eq. potassa,
3 HO, = 3 Eqs. water,
KO, 2 St, 3 HO, = 1 Eq. of the more acid stearate of potassa.
2 KO, St = 1 Eq. neutral stearate of potassa.

The occurrence of these decompositions, which ensue equally with the margarates and oleates of potassa and soda, as with the stearates, affords an easy explanation of the appearance of the whitish turbidity always produced when soap is dissolved in even the purest water, and show, at the same time, that the alkalinity of soapsuds is solely due to the liberation of caustic potassa or soda; and this it is that affords the possibility of removing fatty impurities in water, which is the sole object of washing with soap.

It is of the utmost importance to the soap-boiler that he be well acquainted with the physical comportment of soaps with solutions of different salts, as, for instance, with chloride of sodium, carbonate of soda, the corresponding potassa salts, chloride of ammonium, and various others. These although not absolutely essential to the formation of soaps are very much concerned in the separation of the foreign matters that render hard soap impure; and are also useful to impart to it the proper amount of water. In practice, a solution of chloride of sodium is always employed for this purpose. The peculiar behavior of soap with a solution of this salt is thus described by LIEBIG:—If a piece of common hard soap be placed in a solution of salt at ordinary temperature, it floats upon the surface without ever being moistened, and if the liquid be heated to boiling, it separates without foam into gelatinous flocculæ, which collect on the surface, and upon cooling unite into a solid mass, from which the solution flows off like water from fat. If the flocculæ be taken out of the hot fluid, they congeal on cooling into an opaque mass, which may be pressed between the fingers into fine laminæ without adhering to them. If the solution is not quite saturated, the soap then takes up a certain quantity of water, and the flocculæ separate through the fluid on boiling. But even when the water contains one four-hundredth part of common salt, ebullition does not produce solution. If the soap is boiled in a dilute and alkaline solution of salt, and suffered to cool, it again collects on the surface of the fluid in a more or less solid state, depending on the greater or less degree of concentration of the solution; that is, on the quantity of water taken up by the soap. By boiling the dilute solution of salt with soap for a considerable time, the aqueous flocculæ intumesce, and the mixture assumes a foamy appearance, but still they are not dissolved, as the solution separates from them. The flocculæ, however, have become soft and pasty, even after cooling, and their pastiness depends on the quantity of water they have imbibed. By still continued boiling this character again changes, and in proportion as the water evaporating renders the solution more concentrated, the latter again extracts the water from the flocculæ; the liquid, however, continues to foam, but the bubbles are larger. At length a point is attained at which the solution becomes saturated; the larger iridescent bubbles formed just before disappear, and the liquid continues to boil without froth; all the soap collects as a translucent mass on the surface, and now the solution and soap cease to attract water from each other.

If the plastic soap be now removed and cooled, while the solution is pressed out, it becomes so solid as scarcely to receive an impression from the fingers. In this state it is called *grain soap*. The addition of salt, or its solution, to a concentrated alkaline menstruum of soap in water, precipitates the soap in gelatinous flocculæ, and the mixture behaves precisely as solid soap boiled with a dilute solution of salt. Carbonate of and caustic potassa act exactly as salt in separating soap from the alkaline fluid. The application of these facts to the manufacture of soap is obvious. The fat is kept boiling in an alkaline lie until all pasty matters disappear; but the lie should have only a certain strength, so that the soap may be perfectly dissolved in it. Thus tallow may be boiled for days in a caustic potassa solution, of specific gravity 1·25, without being saponified. If the lie be stronger a partial saponification ensues; but being insoluble in the fluid, the soap floats on the surface as a solid mass. By the gradual addition of water with continued boiling, the mass at a certain point becomes thick and clammy, and with more water an emulsion is formed; on continued heating, this becomes perfectly clear and transparent, if a sufficient quantity of alkali be present. In this state it may be drawn out into long threads, which on cooling either remain transparent, or are milky and gelatinous. As long as the hot mass, suffered to drop from a spatula, exhibits a milkiness or opalescence, the boiling is continued, or more alkali added. When excess of alkali is present, the milkiness arises either from imperfect saponification, or want of water; the former is known by dissolving a little impure water, which becomes perfectly clear when the whole is saponified.

If the lie contain lime the mixture is also turbid, but the addition of an alkaline carbonate causes the turbidity arising from this cause to disappear instantly. In order to separate the soap from water, free alkali, and glycerin, a large quantity of salt is gradually added to the boiling mass, waiting after each addition till that portion is completely dissolved; the first addition increases the consistency of the mass, while each successive portion renders it more fluid, till it loses its adhesive character, and drops from the spatula in short thick lumps. As soon as the congelation is complete; that is, when gelatinous flocculæ separate from a clear watery liquid, the fire is extinguished, the soap allowed to collect on the surface, and cooled either on the liquid, or ladled out and allowed to get solid. In being separated by means of salt from a very dilute solution, soap suffers an alteration in composition, the soap so thrown down being a bistearate, bimargarate, or binoleate of the alkali, instead of the neutral compound originally in solution; but when the solution is of moderate strength, the soap is separated unaltered in composition. The same results as those obtained by the use of common salt are also produced, although in a less energetic manner, by chloride of potassium, carbonates of the alkalies, sulphate of soda, acetate of potassa, and chloride of ammonium. Of these, sulphate of soda and chloride of potassium have but a very slight action. Concentrated caustic lies also separate soap from its solution, in the same manner as with common salt; in weak caustic lie, on the contrary, soap is perfectly soluble. On this account soap-boilers, especially at the commencement of the operation, except in the case of cocoa-nut oil, always use weak lies, as the stronger would prevent the necessary amount of contact amongst the ingredients, and very much retard the process of saponification. Not only all foreign matters other than soaps, but also the base of the oils—glycerin—is completely separated from soap by means of caustic or saline solutions, in which it is perfectly soluble. The separation of the small quantities of earthy and metallic soaps, always formed during the process of saponification by means of impure alkalies, requires a distinct operation, termed the *fitting* process, which will be presently alluded to.

The Caldrons.—The boilers or caldrons used in the soap manufacture are formed of cast-iron or wrought-iron plate. Their capacity varies according to the quantity of soap to be produced at each operation. The pan or kettle is fixed in the brickwork, and so built round that the heat acts solely on the bottom. Before the repeal of the soap duty, the waste lies were required to be pumped out at the top, through the mass of soap. Now it is usual to withdraw these from the bottom, by means of a pipe fixed to the boiler. Fig. 503 is a section of the arrangements. The pans are usually cast with a flange at the upper rim, so that if necessary the boiler may be enlarged by adjusting a hollow cone of wood, iron bound, and which is termed the *curb*. It may extend as high as desired, and should be surrounded with mason-work as the rest of the pan. In some manufactories the boiling of the soap is accomplished by means of steam, either conducted directly into the materials in the boiler, or when a too high

Fig. 502.

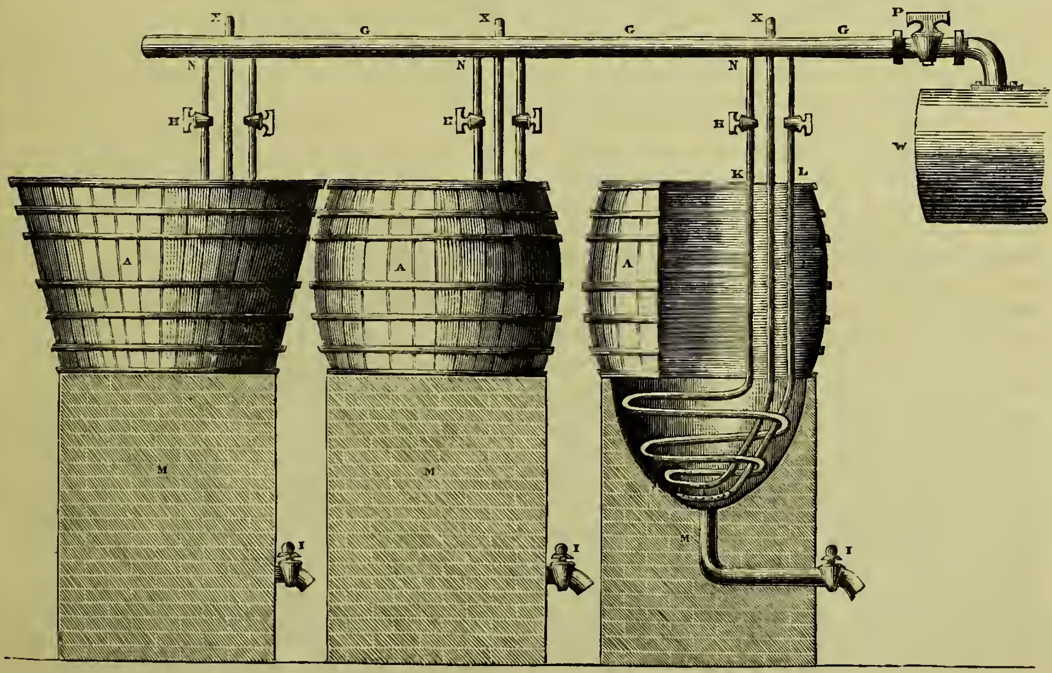
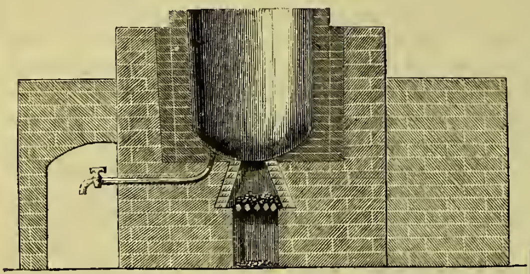


Fig. 503.



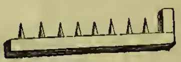
temperature is not desirable, by applying the steam to the outer surface of the caldron. The application of steam is a method of communicating heat to the caldrons, far preferable to the old method of placing the boiler directly in contact with the fire. Not only is there a great saving of fuel, but less attention, and, consequently, fewer hands are required, while the facility of arresting ebullition at any desired moment is of great importance. In the annexed representation—Fig. 502—are shown three caldrons, A, A, A. The main pipe or feeder, G, is attached to the boiler, W, which is stationary, and generally placed against the wall immediately above the kettles or caldrons. These latter are partly of iron and partly of wood, the upper portion or *curb* being wood, well hooped round by iron rings, and the lower portion of cast-iron, and so shaped that the worm can lie closely to the sides, and that the blow-pipe can fit upon the bottom. The cock, I, is for the withdrawal of the spent lies. The pipe, L, serves when necessary to communicate additional heat to the contents of the pan, and is useful also to agitate the mass. In some manufactories the boiling caldrons are made wholly of wood, well fastened by iron clamps.

MANUFACTURE.—*Hard Soaps.*—The process of soap-making varies in some particulars according to the kind of oil or grease to be saponified, though the general method is the same for all. The lies or solutions of caustic soda having been prepared as previously directed, the whole quantity of unctuous material to be saponified at one operation is usually introduced into the boiler at once, and for every ton, from a hundred and fifty to two hundred gallons of caustic liquor of specific gravity 1·090 = 18° Twaddell are added, and the whole is gently heated to ebullition. After boiling for an hour and a half or two hours, the whole forms a viscid emulsion, capable of being drawn out into clear threads. The soap now produced is in solution in the water, and requires to be separated before the spent lie can be withdrawn, and to complete the saponification, a fresh one applied. For this purpose a sufficient quantity of common salt is added, which, dissolving in the liquid, causes the soap—which, as previously observed, is quite insoluble in a strong solution of chloride of sodium—to rise to the surface.

When the soap paste has remained in the boiler a sufficient length of time to have become partially cool, it is ladled out into buckets or pails, conveyed to the frame-room, and poured into the frames to solidify. These frames or *sesses* consist of a pile of rectangular inclosures, measuring internally about forty-five inches by fifteen inches. They should be very smooth, and so jointed as to fit closely together. When piled one upon the other, to the height of three or four feet, they form a tight square well fitted to receive the boiled soap paste. They are tightly bound together by clamps and screw rods. Cast-iron frames, as a substitute for the above, in the manufacture of yellow soaps, are of late introduction. These latter are formed of five rectangular plates, one for the bottom, two for the ends, and two for the sides, so arranged and fastened together as to form a well or reservoir of the same length and breadth as the wooden frames, and about five feet in height. These frames are put together and taken to pieces much more easily than those of wood, and the good conducting power of the iron considerably accelerates the cooling and solidifying of the soap. If the soap is allowed to solidify in the state in which it is run into the frames, it has a rough granulated texture, and is extremely hard. It is therefore usual to mix a small quantity of water with it in the frame, and afterwards agitate the mixture with a wooden *paddle* or *crutch* until nearly cold. By this means it acquires a finer grain, and is not nearly so hard.

The soap having become cold and dry, and in a state to be removed from the frames, which may be known by gentle pressure of the finger making no impression, the iron screw rods which bind the frames together are removed, and each frame is lifted off the soap, which is left a compact mass of the size of the interior of the frame. This mass is then marked round with a kind of iron toothed *scribe* or *dentier*. This instrument is shown in Fig. 504. The teeth are near or distant from each other accordingly as the blocks are desired of small or large size. The mass is then cut by means of a wire, as shown in Fig. 505, into slabs, and these are again sub-divided into bars. These bars are then removed to the drying-room, and piled upon one another crossways, interstices being left for the circulation of air, to facilitate the drying.

Fig. 504



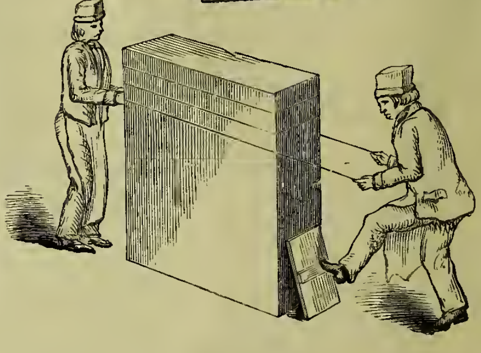


Fig. 505.

The process of the manufacture of soap, though constant in principle, varies in detail in different countries. The following is the method pursued in the United States, as described by MORFIT:—The strength of the lie employed differs accordingly as the oil to be saponified is richer in olein or in solid constituent. The operation is commenced by pouring the lie into the boiling caldron to a third of its capacity. This is then heated to ebullition, and the oil is now poured in. The reaction is such that a magma is immediately formed. The proper formation of this magma is considered to be the most delicate and important part of the whole process, and if badly managed, a much greater quantity of lie is required to form the same weight of soap than otherwise would be. After pouring in the oil, the heat is decreased by opening the doors of the furnace, and when the mixture of oil and lie is complete, if necessary a further quantity of weak lie is added gradually, and with constant stirring during the addition, so as to insure thorough contact. The mass should remain homogeneous; the oil should neither rise to the surface nor descend to the bottom. If oil should present itself, it is then necessary to add more strong or weak lie, according to the capacity of the caldron. If the lie is in excess, a further quantity of oil must be added; always stirring briskly upon any addition of new material. The operation requires from eighteen to twenty hours for completion. It may, however, be greatly accelerated by throwing in the scrapings or the waste of soap already made. An excess of soda is recognized by the liquidity and transparency of the paste. If the oil is in excess it rises to the surface. The presence of a large proportion of common salt in the soda, also prevents more or less the proper formation of the magma. When this is the case to any considerable extent, the use of soap scraps is indispensable. The next step in the process is the removal of the large quantity of water which was required for the ample saponification of the fat. This is effected by the addition of lies containing common salt, and afterwards boiling the mixture from fifteen to twenty hours, constantly stirring during ebullition. When the mass opens in different places, the separation is complete. The fire is withdrawn, and the whole is now allowed three or four hours' repose, after which the settled waste lie is drawn off. A further quantity of lie, charged with common salt, is now added, and the mixture is gently boiled; being careful to remove from the sides of the caldron any adhering soap, so that all portions may be in contact with the lie. The mass now acquires more consistence. After some hours' repose, the settled waste lie is again withdrawn. Lie of specific gravity 1·10 = 20° Twaddell is poured in, and the mixture is again boiled; by this it acquires a still greater consistence. After continued boiling for about three hours it is allowed to deposit, and the waste lie is again drawn off. This operation is repeated once more, but with strong lies, being careful to stir the paste while being heated, so that the whole may form a homogeneous mass, and allowing only a gentle ebullition. The soap at this stage begins to acquire firmness. The boiling with lie several times successively, serves not only to complete the saponification, but to wash and purify the soap. That it may be perfect, it is necessary to repeat the operation four or five times. As soon as complete, the fire should be withdrawn, and the mass allowed repose to settle and become somewhat cool, and then ladled out and conveyed in buckets to the frames.

WHITE SOAP—CURD SOAP.—The unctuous material employed in the production of this soap may be tallow or lard, or olive, or well-bleached palm oil, or mixtures of these in almost any proportion. To produce one ton of soap, from ten to fourteen hundredweight of tallow or olive oil are required. The process of saponification is conducted as above described, with but slight variation, attending more particularly to the complete removal of the *alumino-ferruginous* impurities of the lie, which otherwise impart to the soap a coloration more or less intense. Their removal is effected by boiling the soap several times with fresh lies, or by thinning out the soap with a little lie, and applying gentle heat, then covering the caldron carefully and allowing it to settle. The upper strata of soap is afterwards ladled out and run into the cooling frames. The average composition of ordinary white tallow soap is—of alkali one part, of fatty acids about nine parts, and five to eight parts of water. In England by far the greater quantity of curd soap produced is made from tallow or mutton suet and soda only. Some manufacturers, however, substitute for one-fourth of the tallow as much lard or olive oil, and a soap is produced greatly superior in quality, and less liable to change by exposure. Soap made solely of tallow is, besides, inconveniently hard, and very difficult of solution. In France, and on the Continent, when tallow is saponified, olive oil is always added in the proportion of twenty to twenty-five per cent. of the oleaginous material. In England lard is not unfrequently used as the softening agent; and when applied in about the same proportion answers every purpose, while it has the advantage over olive oil, that it does not detract from the whiteness of the soap. The advantages gained by the addition of lard to olive oil or to tallow may be summed up as follows:—The soap remains unaltered for a longer period, does not emit the disagreeable odor of tallow, and the saponification is more perfect, as the excess of olein in the lard or oil compensates for the large amount of stearin in the tallow, thus inducing a more ready and perfect union of the alkali and oily acids. English white or curd soap is largely used by the cloth manufacturers of Yorkshire, and the lace and stocking bleachers of Nottingham. Tallow is not saponified to a very considerable extent on the continent; but in its stead, olive oil mixed with about one-fifth of rape oil is used in the manufacture of hard soaps. This addition of rape oil is always resorted to, because olive oil alone yields a soap as hard and compact, and as difficultly soluble, as soap made wholly of tallow and alkali. This, however, is not the case with rape oil, and other oils of a similar nature—that is, such oils as become thick and viscid by exposure; experience having demonstrated, though the reason is as yet unknown, that the oils which turn viscid the soonest by exposure, yield with soda softer soaps than those made with oils which, like olive oil, remain long limpid under the influence of the air. The admixture of rape oil with olive oil has therefore the effect of modifying the degree of hardness of the soap, just as when lard is saponified in conjunction with tallow.

YELLOW SOAP.—This variety of soap differs from the preceding and other kinds, inasmuch as a considerable quantity of *resin* enters into its constitution. This substance, as previously observed, is capable of entering into combination with the alkalics, to produce a detergent compound soluble in water. Besides the resin, or common fat, or inferior tallow, palm oil is also used to a considerable extent. The usual proportion of palm oil and resin are three and a half parts of the former to one of the latter; sometimes the proportion of resin is still greater, and the soap produced is then soft and dark colored. When the saponification of the oil is nearly complete—that is, at the last charge of the lie—the resin is introduced in a state of coarse powder, and well mixed with the soap by agitation. The mixture is then boiled for some hours; a small quantity of lie being added from time to time, if necessary, to preserve an excess of alkali until the soap is completely formed, when the lie may be withdrawn and one or two waters, or else weak lies, applied successively with agitation for the purpose of washing and purifying the soap. The resinous scum being removed for another operation, the soap is conveyed to the iron frames to solidify. Yellow soap usually contains, to one part of soda, from ten to eleven parts of oily acid and resin, with from twenty-four to fifty per cent. of water. If it contain a large proportion of water, it has just the same appearance as when it contains only a small proportion. When anything like fifty per cent. is present, it has been added while the soap was in the frames, for the purpose of fraud. If tallow or other grease be employed in the manufacture of yellow soap, instead of palm oil, the following is the mode of procedure:—Two thousand pounds of the oil or fat, six hundred pounds of resin, and from a hundred and fifty to a hundred and seventy-five gallons of soda lie of specific gravity 1·075 to 1·150 = 15° to 30° Twaddell, are run into the boiler, and when the whole is melted, the mixture is heated to ebullition, stirring carefully all the time to prevent the resin adhering to the bottom and sides of the caldron. Should the mass begin to swell out, the heat must be decreased. The first boiling should be continued not more than two or three hours, on account of the facility with which the combination of the fat and alkali is effected. After six hours' repose the exhausted lie is withdrawn, and fresh substituted, and the whole is again boiled for three hours or more. After another repose of six hours, again draw off the spent lie, and renew it with fresh. The ebullitions are thus continued, day after day, until the soap has acquired a proper consistence, which may be ascertained by taking a small portion, and when cool, squeezing it between the thumb and finger. If hard thin scales are formed, it is finished, and after having boiled briskly the fire is removed; but if greasy, clammy, and soft, it is not perfect, and it is necessary to add more lie and reboil. The soap is now to be cooled by adding three bucketfuls of lie, and after two hours the liquor is withdrawn. Six or eight bucketsful of water are now added, and the whole is again briskly boiled, stirring constantly until the soap is melted. A little of the boiling paste is now removed on a wooden spatula, and if it run clear from the lie, more water is added, and the boiling is continued. If it should not run, too much water has already been added, and a half pailful of strong solution of salt must be thrown in.

The most delicate part of the operation is that of boiling, and it therefore requires particular attention. That it may be complete, the soap should, when a portion is taken on a spatula, and the latter is held in an oblique position, shake and disperse tremulously, as would a body of gelatinous consistence. Then the fire may be withdrawn, and the soap considered as finished. In France yellow soap is produced by a similar process as the other kinds of common soap, adding at the commencement of the operation fifteen to twenty per cent. of resin. Some manufacturers make a soap with but five to ten per cent. of resin, and this being lower-priced than soap made entirely of grease, has a more extensive sale, and is preferred especially for domestic purposes. By its property of dissolving more readily in sea-water than other soaps, it is also well adapted for use on shipboard. The common brown soap is made as the preceding, but by using a greater proportion of resin, and substituting for the tallow, either in whole or in part, the common kinds of grease, such as soap fat, bone fat, *et cetera.*

MOTTLED SOAP—MARBLED SOAP.—In the manufacture of this variety of soap, the same kinds of materials are used as for white soap, and its different appearance arises from the different mode of treatment of the soap, after the completion of saponification. By a reference to the general process of soap-making given above, it will be observed that even after the complete formation of soaps, that is, when the whole of the oil or fat used is decomposed, and the oily acids have entered into combination with alkali, the soap still requires further treatment before it is brought into a marketable condition. It exists now in the form of immovable globules, and it is necessary to cause these to coalesce into a homogeneous mass. This is effected by a process termed *fitting*, which consists in the fusion of the contents of the boiling caldron in a weak lie, or in water, and afterwards boiling the whole for a longer or shorter period, according to the kind of material operated upon, the mass being prevented from boiling out of the copper by dashing shovels into it, so as to break the froth and favor evaporation. During this process in making white or curd soap, the more or less colored impurities of the materials termed *nigre* or *nigger* fall to the bottom; but in making mottled soap, the mixture is left in a thick or viscid state, so that the impurities cannot subside, and is transferred to the frames in this condition. To produce a good marbled soap, it is necessary that this latter operation be very carefully conducted; as, if too great a quantity of liquid be added, or if the mixture of soap and water or weak lie cools too slowly, all the coloring matter falls to the bottom, leaving the upper stratum of soap perfectly white, while, on the other hand, if it becomes too quickly cold, the soap remains in the granular condition. THÉNARD compares the separation of the coloring material to a kind of crystallization, and MORFIT ascribes the result to the formation of an *alumino-ferruginous soap*, and the lesser solubility of this at a lower temperature. The lower veins in mottled soap appear to be due to the presence of an exceedingly minute trace of sulphide of iron, derived from the last service of lie, in which it exists in solution as a double sulphide of sodium and iron. As a perfectly colorless lie, apparently free from every trace of iron, will produce mottling if allowed to separate slowly from soap, it has been questioned whether iron is really the coloring agent; but, as noticed by PARNELL, this seems to be proved from the fact that the ash which remains after the calcination of the brown parts of such soap, affords to reagents a sensibly larger quantity of iron than the white parts of the same sample of soap. Granting that the lie used may be free from iron, which, however, is very rarely the case if an alkaline sulphide be present, this has a solvent action on metallic iron, and will therefore take iron from the pans or boilers used; and even supposing the lie to be free from alkaline sulphide, it becomes a matter of doubt whether, in the process of boiling, a portion of sulphate may not be reduced to the state of sulphide by prolonged contact with the organic matter. In some cases—and in such, iron must be present in some form or other—the mottling is produced, or at least the proportion is increased by sprinkling on the surface of the soap, after being boiled with the last service of lie, a small quantity of very strong sulphuretted lie, which produces the mottling by filtering slowly through the mass of soap. At Marseilles and other places where olive oil is used in making soap, a quantity of sulphate of iron is added; in which case the mottling is produced, both by the black sulphide of iron, and by the oxide of iron—the red portion—which latter combines with fatty acids, producing a true ferruginous soap. The quantity of copperas requisite is about eighteen ounces to four hundred and fifty pounds of oil or fat. It is added first mixed with weak lie, and should be poured in during the coction of the soap, and before it has acquired too much consistence. When the soap is ladled out of the boiler, it is of a uniform slate tint; but as it becomes cool, the metallic portion separates into nodules, and by the trickling of the excess of lie through the mass, they assume those forms to which the term *mottled* is applied. By varying the proportion of sulphate of iron a tint is produced of a lighter or darker hue. Soaps containing this have exteriorly a rusty color, owing to the sesquioxidation of the iron at the expense of atmospheric oxygen, and this shade may be deepened by the addition of venetian red, or colcothar, into the particular tint to which the French apply technically a term signifying *hidden red*, and which upon the deep blue produces the appearance of marble, as seen in the variety known as *castile soap.* This peculiar tint may be communicated as well before as after the true marbling; for which purpose it is necessary to thin out the colcothar with water, and in adding it to incorporate it well with the soap. Generally, in the preparation of mottled soap, less care is exerted in the choice of materials than for white soaps, and the heterogeneous mixture of fatty substances, known as *kitchen stuff*, usually forms one of the materials.

COCOA-NUT OIL SOAP.—Cocoa-nut oil is very easy to saponify, and is used to a considerable extent in the manufacture of white soap, as well *per se*, as in admixture with other oils and fatty matters. The disagreeable odor of this oil is removed most effectually and conveniently by boiling in a wooden vessel by means of steam, with a mixture of six pounds of sulphuric and twelve of hydrochloric acid to each tun of oil. The oil so purified is heated in the boiling caldron, with the addition of a portion of olive or some other readily saponifiable oil or fat, and the soda lies are gradually introduced in the usual manner. Towards the conclusion of the process of saponification, a quantity of caustic potassa lie is thrown in, and the boiling is continued as long as may be necessary. The soap thus formed requires, for its separation from the lies, a much larger proportion of salt or other saline matter, than the soaps formed of tallow, palm oil, or olive oil. Otherwise the process of separation is the same as for other soaps. Pure cocoa-nut oil soap, by the usual method of saponification, can only be obtained by the use of a very large quantity of common salt, and then contains so very little water, or is so extremely hard, that it cannot be cut with a knife. On this account the usual mode of proceeding is not followed in the production of this soap. The principal distinction between cocoa-nut oil and other oils and fats is, that while the latter are most readily saponified by weak lies, cocoa-nut oil is quite unacted upon until the lies have obtained a considerably higher degree of concentration; saponification then suddenly commences, and proceeds with extraordinary rapidity. Only the strongest soda lies are employed in the production of this soap, and by taking pure and perfectly caustic lie, the use of salt in purifying the soap is dispensed with. Pure cocoa-nut oil hardens much too quickly to exhibit any distinct formation of curd, and is consequently incapable of marbling of itself; it is very white, translucent, exceedingly light, and forms a good lather, but has always a more or less offensive smell.

An important property of cocoa-nut oil is its power of combining with more water than can even be incorporated with tallow soap, and this property frequently leads to dishonest practices. Cocoa-nut oil actually produces no greater quantity of soap than an equal weight of tallow; but the soap from the former can easily be made to absorb one-third more water or lie, and, at the same time, exhibit no want of consistence or softness, as would be the case with other soaps. The more rancid cocoa-nut oil be, the more readily is it saponified.

As previously remarked, cocoa-nut oil is not usually saponified alone, but is added to other oils for the purpose of producing quickly solidifying soaps containing a large proportion of water. When equal parts of cocoa-nut oil and tallow are used, the soap has the smell of common tallow soap. The boiling is continued until a specimen exhibits the proper consistence under the thumb. Tallow itself could not be saponified under the same conditions; but the saponification begins with the cocoa-nut oil, and the tallow is then saponified by means of the presence of the cocoa-nut oil soap. The different varieties of this soap are marbled artificially. The blue or red coloring matter is rubbed up with a little of the soap, or better, with a separate portion of good cocoa-nut oil soap, until the whole acquires a red or blue color. This is then placed in alternate layers with the colorless soap; and by stirring the mass together streaks and veins are produced in all directions.

MARSEILLES SOAP.—This variety of soap is produced by the saponification of olive oil alone. The process does not materially differ from that described for white soap. The duration of the operation is longer or shorter according to the quality of the oil. Some manufacturers use, in the fabrication of this soap, a certain proportion of poppy oil with the olive oil; and the addition is rather beneficial than otherwise, as the soap produced is less hard, and consequently more easily applicable to detergent purposes. It is at present manufactured on a considerable scale in this country.

An improvement on the old method of soap-making was invented by DUNN, and has been already alluded to. It consists in the application of streams of air to the materials, whilst in the course of saponification. The air is forced below their surface by means of a pump; and the saponification is said to be greatly accelerated, and the process otherwise much improved. The following is the method as stated by MORFIT:—Into each of the ordinary boiling caldrons a circular ring of pipe of about one and a half inch bore, and perforated with small holes, is fixed in the well of the kettle, just below the flange or joint, keeping it sufficiently off the bottom to allow a stirrer to be used to scrape the bottom when necessary. The pipe is supplied with atmospheric air from a cylinder blast, or other suitable forcing apparatus, and is connected with the latter by means of a pipe attached thereto, and rising up to the top of the kettle, where it is furnished with a stopcock and union-joint, for the purpose of connecting or disconnecting the parts of the pipe within and without the copper. For a clean yellow soap ninety gallons of lie of specific gravity 1·14 = 28° Twaddell, are run into the caldron. The fire being kindled, the caldron is charged with two thousand and fifty pounds of grease; and as soon as the lie is at or near the boiling point, the blast is commenced, keeping up a brisk fire so as to continue the materials in the kettle as near ebullition as possible. When the lies are exhausted, an additional quantity is gradually added until the grease, oil, or fatty matter is taken up. Five hundred and fifty pounds of resin are then added—a bucketful at a time, with more lie occasionally, until three hundred gallons of the strength above-mentioned have been used, keeping the blast in action the whole time, and the contents of the kettle as nearly boiling as possible. When the whole of the resin is melted, and thoroughly incorporated with the saponaceous mass, and the strength of the lies taken up, the blast should be stopped, and the contents of the boiler briskly boiled, and then allowed to rest, that the spent lies may separate and deposit. These being now drawn off, the soap is then brought to strength by fresh lies as in the ordinary process of soap-boiling. During the operation of the blast, the soap must be kept in an *open* or *grained* state; and for this purpose salt or brine is to be added when necessary. Experience has shown that it is better not to make a change of lie during the operation of the blast, when lie of the strength above-mentioned is used; but if weaker lie is employed, one or more changes may be made. It is found desirable, also, that the soap should be kept in a *weak* state during the passage of the streams of air through the materials; otherwise it is apt to swell up, from the air hanging in the grain; and this is found troublesome to remove, requiring long boiling. If dark-colored materials are used, it is well to keep the blast in operation three or four hours after the resin is melted; provided the soapy mass is kept *weak* and *open* or grained.

Another improvement in the manufacture of soaps was invented by Mr. ANDERSON, by means of which the soaps are more completely purified. This is described by MORFIT as follows:—In the manufacture of yellow or resin soap, the ordinary process is that of boiling the materials upon successive portions of alkaline lie until they become *strength;* that is, until the oily matter is perfectly saponified, after which the curd so produced is subjected to a purifying operation termed *fitting*, performed as follows:—The lie used in boiling to strength is carefully pumped off from the soapy paste; and the latter is diluted with weak lie or water, and boiled to the proper consistence. After two days' repose the lies settle out of the perfect soap, and there is found below the latter an inferior or second quality of soap termed *nigre* or *nigger*. The perfect soap is cleansed or lifted off carefully from this, and transferred to the cooling frames; the mass of imperfect soap either being added to the next charge, or concocted into an inferior soap. The process followed in making curd soap, is to boil the materials upon successive lies until they become saponified; after which, and when the curd is of proper consistence, it is removed carefully to the cooling frames without further treatment. The invention of Mr. ANDERSON, it will be observed, does not interfere with the usual mode of producing the soap, but refers only to its purification, and begins at that point where the materials having been properly saponified, the soap *ribbons out* well on the finger. At this stage, instead of boiling out the head, and finishing as heretofore practised, the new process is commenced by pumping out or drawing off the strong lie on which the materials have been boiled, and then adding weak lie or water in successive portions, and boiling the whole until the mass assumes a proper appearance for fitting. The whole is now allowed to stand at rest for from twenty-four to forty-eight hours, or until the *nigger* or imperfect portion of the soap is deposited. This latter may then be separated, either by pumping it off from under the purified compound into an adjacent kettle, or by removing carefully the upper stratum of purified soap by means of ladles or buckets.

Whichever method be pursued, the cleansed material must now be treated with the proper finishing lie for curd soap; which being added, the whole is boiled until the soap becomes of sufficient consistence to be transferred to the cooling frames. When the materials employed in the production of this soap are very impure, the fitting or purifying process as above described is repeated one or more times; in which case after the first separation of the imperfect soap, the remaining partially-purified material is treated with a lie only of moderate strength, instead of the ordinary finishing lie, and the whole is boiled with weak lie or water until sufficiently diluted to allow the proper performance of the fitting process; after which, time is allowed for deposition, the imperfect soap is again removed, and after the addition of the finishing lie, the remainder is boiled to a curd as before. The further treatment of the separated *nigger* or imperfect soap and its conversion into mottled soap, is effected by adding to it in an ordinary caldron the usual finishing lie for a mottled soap, and boiling until it is of proper consistence to be removed to the frames. The quantity obtained from one charge of soap by the fitting or purifying process, is not enough to be conveniently boiled by itself; it is therefore set aside, and six or more batches operated upon at one time.

Soft Soap.—This variety of soap differs in many essential particulars from those already described. The alkali used in its production is potassa exclusively, and the oil, either in whole or in part, a drying oil, as that of hemp seed, poppies, *et cetera*, or fish oil, as whale or seal oil. The theory of the reaction of potassa upon fats and oils is precisely the same as in the case of soda. Soaps, with potassa base are, however, manufactured on an entirely different system to those of soda or hard soaps. In the latter, the soap is withdrawn from the lie when only a portion of the oil has been saponified, and fresh lies are added until saponification is complete.

In the production of potassa or soft soaps, no lies are separated during the whole course of operation; the only object being the combination of the potassa with the fat or oil. Potassa soap, therefore, of course contains the whole of the base of the oils or glycerin, which is expelled from combination by the stronger base, as well as the impurities always existing in the lie, as carbonate of and caustic potassa, chloride of potassium, sulphate of potassa, and in small quantities, many other salts, which in the manufacture of hard soaps are removed in the exhausted lies. Potassa soap, also, always contains a much greater proportion of water than hard soaps, the quantity being in the majority of instances from fifty to sixty per cent. If desired, the glycerin of the fat and saline impurities of the lie might easily be removed by the application of strong lies towards the completion of the process, but on the large scale such a system is never pursued. A much larger proportion of alkali is consumed by a given weight of oil or fat, when saponified by potassa, than when soda is used, one part of pure potassa being taken up by from four and a half to five parts of oil; and hence the quantity of real soap produced from a given weight of oil or fat when saponified by potassa is considerably greater than when the alkali used is soda; and this quantity is still further augmented by the large proportion of water, together with the glycerin and saline impurities always contained in the lies, and which, as above stated, are not removed from the soap. From the great analogy which exists between soda and potassa compounds, it would be expected that potassa soap would be separated from its solutions by chloride of potassium, as soda soap is by chloride of sodium. This, however, is not the case, as when to a solution of potassa soap, procured by treating oils or fats with caustic potassa lies, a considerable quantity of chloride of potassium is added, no separation of soap takes place; the salt dissolves in the soapy mixture, and the solution remains clear. Potassa soap can only be separated from the lies and eliminated glycerin by adding strong potassa lies after the soap is complete, and the excess of alkali and the glycerin may then be allowed to subside, and subsequently be more completely removed by placing the soap to drain. On the large scale, however, as before observed, soft soap is never separated as above; the soap solution is boiled down until homogeneous and of a proper pasty consistence.

The process of manufacture of soft soap is as follows; the proportions of oil and lie being regulated according to the strength of the latter, and the qualities operated upon at once varying with the greater or less capacity of the boiling caldron. According to **Morfit**, whose extensive experience in the soap manufacture renders his remarks of great value, the larger the caldron the better and more economical. To be properly proportional, the diameter should always be greater than their depth, and should be only half filled with material, as the soap when boiling swells up and rises considerably. In some soaperies the whole of the oil and tallow is introduced at once, together with a portion of the lie, and the remainder of the lie is added after some hours' ebullition; in others, both the oil and lie are introduced gradually. The lie should, indeed, always be gradually added, and in small quantities at a time, spreading it superficially over the whole mass. As soon as the two clear liquids, separately introduced, unite together, the whole becomes much thicker, and in some cases boils quietly, but in others swells up into froth. In the latter case it must be thrashed with a stirring pole, and dosed with a sufficient quantity of lie to lessen the commotion and prevent loss of the material by running over. The caldron requires to be constantly watched while over the fire. If too much lie is added at the commencement, no union is effected between the oil and the alkali; and if the lies are too strong they seize on the oil too rapidly, and instead of becoming thick and viscid, the mass becomes clotted. This latter inconvenience may be remedied by adding lies of a lower degree of strength. If the lies are not sufficiently strong, combination ensues so tardily that part of the superabundant water must first be expelled by evaporation before a perfect union between the oil and alkali can be effected. When combination is perfect and the great foamings have subsided, the pasty mass should become clear and transparent, and free from clots or granules, and no acrid taste should be perceptible. To ascertain if this be the case, a small sample is taken out and cooled. If it should not be of proper consistence and free from opacity, the boiling is continued, and after some time another sample is taken, and so on until the soap is properly finished. If the test sample thickens on cooling, has a brown color, is perfectly homogeneous, and is not ropy when worked between the fingers, the soap is finished, and the fire should at once be withdrawn. A fair criterion of the quality of the soap is said to be furnished by a peculiar phenomenon observable during its cooling; a little opaque zone forming around the test-portion taken from the caldron for an assay, indicates perfect saponification, and is called *strength*, the absence of which denotes a deficiency in strength; and when the zone vanishes soon after having made its appearance, the soap is said to have *false* strength. When it comes in the best form the soap is perfect, and may be secured in that state by removing the fire, and then proceeding as subsequently directed.

To allay the foaming and render the finished soap fit to be transferred to the barrels or casks without endangering its detergent quality or diminishing its causticity, the soap should be cooled as rapidly as possible. For this purpose a quantity of ready-made soap—a ton or more, according to the size of the caldron—is added to the hot mass. This, in melting, rapidly abstracts a portion of the heat of the recently made soap, until the degree of that and its own is uniform. The foaming having subsided, the soap is racked off into the barrels, in which it is sent away. In the manufacture of soft soap MORFIT observes, that it is better that the boiling should be too much than too little protracted. Soap which is not sufficiently cooked, changes and spoils, while the only disadvantage produced by excessive boiling is a diminution in the quantity of the product. The usual time requisite for a charge is six or seven hours, but varies with the strength of the lies, the temperature of the atmosphere, and other incidental circumstances.

In Great Britain a small proportion of tallow is usually introduced as one of the materials for the production of soft soap. This addition is for the purpose of producing the solid white granulations of stearate of potassa termed *figging*, because the soap then resembles the granular texture of a fig. Hence British soft soap presents the appearance of a brownish transparent body, through which white grains are disseminated. These figged granulations do not usually make their appearance until two or three weeks after the soap has been made, and during the hot summer months they do not appear at all. They are improperly considered to be a proof of the good quality of the soap, and hence the figged appearance has been imitated by the admixture of starch. Messrs. LUND and UNSWORTH of Liverpool are said to be the largest makers of soft soap in England. They generally turn out fifty or sixty tons weekly of a most excellent article.

The Scotch process for manufacturing soft soap is as follows:—Two hundred and seventy three gallons of whale or cod oil, and four hundred pounds of tallow are introduced into the soap pan, together with two hundred and fifty gallons of potassa lie, of such strength that one gallon contains six thousand six hundred grains of real potassa. Heat is now applied to the pan, and as the mixture approaches the boiling temperature, much froth appears, and to prevent boiling over, it is beaten down on the surface. Should it subside quickly into a doughy looking paste, it is an indication that a too strong lie has been used. Its proper appearance is that of a thin glue. There should now be added about forty-two gallons of a stronger lie, equivalent to eight thousand seven hundred grains of potassa per gallon, and after a short interval, an additional forty-two gallons; and thus successively until nearly a total of six hundred gallons has been introduced. After properly boiling, to complete the saponification of the fats, soap will be obtained amounting in quantity to six thousand four hundred pounds, from the above proportions of materials.

American soft soap, MORFIT states, differs very little from the preceding in its mode of manufacture; two hundred pounds of oil saponified by seventy-two pounds of potassa in lies of specific gravity 1 110 = 22° Twaddell, yielding four hundred and fifty pounds of finished soap. Fish-oil soft soap has usually a dark-brown color, and that made from refuse fat and oil, a dirty-white shade. Soap made with colza oil is slightly bluish. When hempseed oil is used, the soap has a greenish color. The latter is by some consumers preferred to other kinds of soft soap; and hence ordinary soft soap made from fish oil is frequently tinged green by adding a small proportion of powdered indigo, or a solution of indigo in alkali, the yellow of the soap forming a green with the blue of the indigo. Soft soap is always of a pasty consistence, and even if excessively boiled, does not harden, but becomes scorched and dry. In this country it is chiefly used for fulling, and for the scouring and cleansing of woollen stuffs. Being possessed of greater solubility, and having a much more powerfully detergent action, it is also especially applicable for scouring floors and wooden utensils. In Germany, Belgium, and Holland, it is also used for washing linen, which thereby acquires a most disagreeable odor of oil When chloride of sodium is added to soft or potassa soap, decomposition ensues, the chlorine of the salt seizes the potassium of the soap producing chloride of potassium; and at the same time, the sodium takes the place of the potassium in the soap, and a hard or soda soap results. The proportions recommended by PELLETIÉR and others for the conversion of soft into hard soaps, by means of the above-mentioned decomposition, are six pounds of salt to every three pounds of oil, and the solution of the salt in water is to be added in small portions and gradually to the soap, the latter being in a state of ebullition. The soda soap produced separates quickly from the lie, and the operation is terminated in the usual way. This process for producing hard soap is of great importance in those countries where soda is not to be procured, as potassa and its salts may be substituted for the latter in the process of saponification.

SILICATED SOAPS.—Many varieties of soap are met with in commerce termed silicated soaps. They are produced either by the addition of silica itself or an alkaline silicate to the soap paste, just before cooling and solidification. Under this title are included also those soaps admixed with pipe-clay, and matters of a similar nature, which, though not strictly silica soaps, are usually classed with them. Sand soaps differ from silica soaps inasmuch as in the latter the admixture has been prepared artificially, while in the former common white sand is the silicious ingredient, and the only preparation it has undergone is finely sifting. In the preparation of sand soap, the finely-sifted sand is added to ordinary white soap and thoroughly incorporated with it while in the pasty condition, in the proportion of seven or eight per cent; and as soon as the mass has cooled, it is taken from the frame and cut into tablets or moulded into balls. Of the three silicated soaps, the first that claims mention is that prepared by Mr. GOSSAGE's patent process. It consists in the introduction into soaps prepared from fatty or resinous materials of a highly concentrated solution of silicate of alkali. The process for the preparation of this silicate, termed also *soluble glass*, is described in the specification as follows:—When soda is used as the alkaline solution to be combined with silica, nine parts of soda ash are mixed with eleven parts of clear sand, and the mixture is to be fused in a reverberatory furnace, provided with a tap-hole through which to allow the finished product to run off. Sufficient heat is to be applied to the mixture, stirring from time to time until combination has been effected; the product is then drawn, and received either in metallic moulds, or in moulds formed of damp or moistened sand. The charge for a furnace having a bed or sole measuring sixty square feet, is about a ton of the mixed sand and alkali, and each charge requires four or five hours to be properly fused and combined. For the preparation of silicate of potassa the proportions are equal weights of crude carbonate of potassa and sand, and these are melted exactly as in the production of silicate of soda. It is always desirable to use such proportions of alkali and sand for the production of the silicate, that the latter may be almost wholly soluble in water; when the alkali is deficient, however, this is not the case, and to obtain perfect solution, it is necessary to use as the solvent a solution of caustic soda or potassa.

The solution of the perfect silicate may be effected simply by grinding the latter to powder, and agitating this in a pan containing boiling water; but a much preferable method of solving is, by the employment of an apparatus consisting of a vessel formed of iron plates, or other suitable materials, which vessel is fitted with a perforated diaphragm or false bottom placed about mid-way between top and bottom. The silicate, first broken into small lumps, is placed upon the false bottom, and hot water is introduced into the vessel to a sufficient height to cover the pieces of glass to be dissolved. Steam is then introduced into the water so as to maintain the latter at a high temperature.

As the glass dissolves, it communicates additional gravity to the water, and the heavier solution descends in the vessel whilst the lighter fluid rises, and coming in contact with the glass also dissolves it, and acquiring density again descends. In this manner a continued circulation of the fluid takes place, and the glass becomes nearly all dissolved, yielding a strong solution.

After allowing undissolved matters to deposit, the solution is transferred to a cast-iron evaporating pan, and by the application of heat concentrated until of specific gravity 1·450, when it becomes viscous on cooling, and is then in a condition to be added to the soap. When the solution of the silica is to be added to a soda soap, the latter, prepared in the usual manner, is to be transferred from the caldron into a tub or pan, termed the mixing vessel, capable of containing about fourteen hundredweight of soap, and the viscous solution of silicate of soda is to be added in such proportions as to yield the particular quality of soap desired to be produced; and the mixture is then well agitated by means of crutches or paddles. The soap and the viscous solution should be each at such a degree of heat that the mixture, when formed, may be at a temperature of 160°, and the agitation is to be continued until the temperature is reduced ten degrees, that is, to about 150°. The mixture is then transferred to the cooling frames, and agitated therein by means of crutches, until it becomes of such consistence as to render its continuance no longer practicable.

Although the mixture of the solution of silica with the soap may be effected by means of crutches worked by hand, as above described, it may be stated that when a more rapid agitation is applied than can be effected by this means, the soap produced is a more perfect mixture, and of more uniform quality.

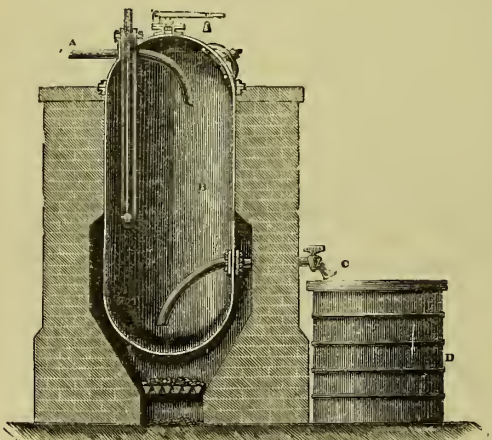
For admixture with soft soap, the soluble glass is formed by the fusion of a mixture of sand and potassa, as previously mentioned, for the preparation of a silicate of potassa. This is dissolved, and after concentrating the solution to the viscous condition, it is mixed with the soft soap, exactly as described in the case of soda or hard soaps. As the proportional amount of alkali contained in a mixture of soap with soluble glass is greater than that contained in the unmixed soap—if it is desired to reduce this amount, as the excess of alkali may be injurious for some purposes to which the soap may be applied, it is effected by the addition to the solution of the silicate of sulphuric or hydrochloric acid, previously to its reduction to the viscous condition. The mixed silicated soaps may be obtained of any requisite degree of hardness by the greater or less concentration of the solution of soluble glass. The compound soaps produced by the above process, the patentee states, are possessed of valuable detergent properties, independently of the real soap contained in them.

In the process invented by Mr. SHERIDAN for the preparation of silicated soap, either calcined flint, or quartz, or sand is used for the production of soluble glass. If sand is the silicious ingredient, he directs that it be mixed with carbonate of soda in the proportion of one part of sand to three of soda, and the mixture is then to be calcined to fusion in a reverberatory furnace. The product of calcination is drawn out into water and dissolved by the aid of heat. Thus far the process resembles that of Mr. GOSSAGE. Mr. SHERIDAN, however, now directs that a current of carbonic acid be passed through the solution of silicate of soda, whereby the silica is displaced from combination and precipitated in a gelatinous form. From this the liquid containing the soda, reconverted to the state of carbonate, is withdrawn, and evaporated to dryness for use again; the precipitated silica is mixed with caustic soda or potassa lie of specific gravity 1·1515 = 30° Twaddell, and boiled for eight hours, with constant stirring, until it becomes a homogeneous mass. This latter part of the process seems a very useless operation. It is simply the destruction of a compound already in the liquid condition, and its reproduction in exactly the same state, but by another and more objectionable mode of treatment—objectionable because combination between silica and an alkali is effected much more easily and perfectly by fusion than by ebullition of the materials together with water. When the silicious ingredient is flint or quartz, the calcined material is to be reduced to nearly an impalpable powder by wet grinding with horizontal stones. The powder obtained is thinned out with about twenty per cent. of water, and then boiled with caustic soda lies of the strength above mentioned, for eight hours, or until it becomes a homogeneous mass. In this condition, in which it is technically termed *detergent mixture*, it is ready to be mixed with the soap paste.

A method for the preparation of silicated soap was also invented by Mr. Dunn, in which either silica itself, or an alkaline silicate, is made to unite with soap under steam pressure. According to the author of this process, the method is also applicable to the manufacture of soap even when silica is not an ingredient, with the advantage over the usual mode of boiling, of effecting a more perfect union of the ingredients in a shorter time, with greater economy, and at a diminution of expense.

The apparatus employed is represented in section, Fig. 506. The boiler, B, should be furnished with a man-hole, safety valve, a thermometer plunged into a mercury chamber, and all the ordinary appendages of such an apparatus. A is the feed-pipe, and C the pipe through which to discharge the finished product. The crushed flint or quartz to be combined with the soap is mixed with caustic soda or potassa lie, in the proportion of one hundredweight of silica to one hundred gallons of lie of specific gravity 1·16 = 32° Twaddell, and introduced into the steam-tight boiler. The fire is then kindled, the valve being so regulated as to allow the temperature of the materials to rise gradually to about 310°, or at a pressure of fifty to seventy pounds to the square inch. When it has remained at this temperature for about three or four hours, the contents are discharged and cooled down. The solution of silicate of potassa or soda thus obtained, according to the kind of alkali used, is added in the proper proportion to the soap paste, either in the caldron or frame after the saponification is complete, and before the soap is become cold.

Fig. 506.



Sulphated Soap.—The variety known to manufacturers and in commerce as sulphated soap, is produced by a process patented by Dr. Normandy. The object of the patent appears to be, to enable manufacturers to produce a soap from inferior oils and fats possessed of detergent properties, and also of a hardness equal to that from oleaginous bodies of much higher value. The great objection to soaps made from the inferior kind of fats, and also to soaps containing more than a due proportion of resin, is their very ready solubility in water, in consequence of which great waste is always experienced when these soaps are used for washing or cleansing purposes. By Dr. Normandy's process, a soap is obtained from the cheaper oil possessed of equal detergent properties, and also of an equal degree of hardness, to that obtained by the employment of the more valuable fats and oils; thus rendering a large class of oleaginous bodies available in soap-making, to which purpose they were not previously applicable. The following, extracted from the specification of the patent, will render the process sufficiently intelligible.

When the soap is made in the usual manner, and is ready to be cleansed, there is to be introduced and crutched into it a certain quantity of neutral anhydrous sulphate of soda, or of neutral sulphite of soda, or of the two salts conjointly. These salts have the property of imparting to soap made with more than the usual proportion of resin, or with those kinds of fat or grease known as *weak goods*, a greater degree of hardness than they would otherwise possess; and of rendering such soaps generally of a paler color, and enabling them to retain their weight better than would be the case without such addition. The soap containing sulphite of soda has, in addition, the property of removing from textile fabrics and fibrous substances the chlorine which they are apt to retain after bleaching. The mode of procedure with the sulphate of soda, or *salt cake*, is as follows:—

The salt is to be treated with a quantity of hot water, less than is necessary to dissolve the whole of it, and to the saturated solution thus obtained as much solution of caustic or carbonate of alkali is added as is necessary to impart to the liquid a faint alkaline reaction. This addition is made not only to saturate any free acids that may be present, but also to remove the sesquioxide of iron always contained in crude salt cake, and which, by this treatment, will be precipitated. When this precipitate has completely subsided, and the supernatant liquor is perfectly clear, as much of the latter is added to the soap paste as is necessary to confer upon it the requisite degree of hardness when cold; the particular quantity varying according to the nature of the fat or oil saponified, or to the proportion of resin present. The mixture of salt-cake solution and of soap are to be thoroughly incorporated by stirring or crutching, continuing the agitation until the mass has become so hard that the stirring can be no longer practised. When the sulphite of soda is used, the patentee recommends that it be dissolved in as little hot water as is necessary for the purpose; and the solution is added to the soap exactly as above described for the sulphate of the same base, or salt cake. If the salt be a bisulphite of soda, or if it is not in a state of purity—in other words, if it contain an excess of sulphurous acid, or be contaminated by oxide of iron—the excess of acid should be neutralized, by adding to the solution of the salt as much carbonate of or caustic soda as will impart a slight alkaline reaction; and after allowing the separated matters to deposit, the clear supernatant liquor is to be introduced and crutched into the soap, precisely as directed above in reference to the salt cake. The usefulness of this invention has been tested and carefully examined by several eminent chemists, among others by HOFMANN, MILLER, and URE, all of whom speak in high terms of its merits; and the Editor is gratified to have this opportunity to add his testimony as to the value of an invention the object of which is to supply a cheap soap as economical to the consumer as that produced by the more expensive fats and oils.

SNELL'S DEXTRIN SOAP.—This soap contains, in a state of admixture, a greater or less amount of vegetal matter, obtained from either potatoes or other sources. It is termed by the inventor dextrin soap; as prepared, however, according to his directions, no dextrin enters into its constitution, but, instead of this, woody fibre and unaltered starch. The method of preparation is said to be preferable to the old plan of combining farina with alum and soda in the manufacture of soap, inasmuch as it insures the perfect incorporation of the admixture with the saponified fats and oils, whereas, when they are previously acted upon by alum and soda, their tendency to union is partially impaired. The vegetal matter used by the inventor is obtained from potatoes as follows:—The washed potatoes are reduced to as fine a pulp as possible, by a revolving cylinder furnished with parallel plates of steel or iron. These plates have fine teeth like saws, the teeth rising just above the surface of the cylinder under a hopper, which receives the potatoes. The pulp falls on sieves or screws below, and passes over the upper sieve. This is a plane of five feet in breadth and eight in length, with one or two bars crosswise, covered with a wire-cloth of thirty holes to the inch. At the top, and about midway down the sieve, are pipes containing water, so arranged that the water shall run from the pipes through small holes the whole breadth of the sieve, the finer parts of the potatoes running through the meshes of the sieve into a vat. The finer parts, termed dextrin by the inventor, which fall on a wooden plane placed under the second sieve, but in a contrary direction thereto, are received in vats, where they are repeatedly washed over sieves of finer wire-cloth until cleansed from all impurities. The grosser parts—fibre—are washed over coarse sieves. The finer parts, having precipitated, are taken up in buckets, and are fit for use; the coarse portion remains in a vat covered with water until required for use, or the dextrin may be dried by any convenient means, and preserved in the dry state. The usual proportion of dextrin to soap is from three hundred to three hundred and fifty pounds of the first, mixed with a hundred and fifty pounds of water, to every ton of tallow or oil saponified. The mixture of water and dextrin having been allowed to stand for an hour, should be further treated with six hundred pounds of water, as subsequently described. The white soap should be made of tallow, and by steam heat; and when as much alkali has been added as can be taken up in the usual way, and when the soap is in a fit state to transfer to the frames, there is to be added from four hundred and fifty to five hundred pounds of dextrin in its wet state; and after being further mixed with six hundred pounds of boiling water, or as much as is sufficient to convert it into a thick paste, this paste is to be poured in by pailfuls into the soap, the latter being well agitated during and after each addition. When the mixture is homogeneous, and has been heated, it may be put into a frame for cooling, and afterwards cut up in the usual way. Before adding the mixture of dextrin and water, the spent lie must be pumped or otherwise withdrawn from the caldron. When, as in the ordinary method of manufacture, yellow soap is made from resin, and is *fitted* or purified from portions of imperfect soap, coloring matters, *et cetera*, it should be heated with steam, and dosed with the proper proportion of dextrin, as above directed. If no resin is used, a larger quantity of dextrin may be applied, and the operation of fitting is not then absolutely necessary. In the manufacture of either the brown or yellow variety of common soap, the addition of a quantity of the fibre, first mixed with a sufficient quantity of water to make it of thick creamy consistence, will render the product, especially when an excess of alkali is present, of much better quality and color, and it will then also dissolve much less rapidly in hot water. If a naked fire is used for the soap thus mixed, the dextrin is liable to become carbonized, and the separated charcoal would then communicate to the soap a black, or at least a darker color, than when steam is applied. The latter should therefore be always used in the above process of admixture.

A person named HAWES some years ago invented a process for the production of soap, in which intimate combination and admixture of the soap ingredients without boiling induces combination and perfect saponification of the fat with the alkali. By this method, the high degree of heat requisite in making soap by the usual process is entirely dispensed with. His mode of procedure is, as follows, described as for tallow; but, according to the inventor, it is equally applicable to the oils and fatty matters ordinarily employed as soap ingredients:—Two tons and a half of tallow, or any given quantity, are taken and melted at as low a degree of heat as possible, and then mixed with the quantity of alkaline lie required to completely saturate the tallow and convert it into soap. The mixing is performed by mechanical means. Ordinary soap boilers' lie is used, preference being given to that made from the strongest and purest alkali. The saponification of the tallow or other fatty matter, may be ascertained by its absorption or combination with the lie, care having been taken, in the first instance, to use a sufficient quantity of the latter; the proper proportion, it must be observed, varying according to the nature of the fat or oil. To each hundred pounds of tallow are required about twenty gallons of lie, made from strong alkali, and of specific gravity 1·125 = 25° Twaddell. An ordinary boiling caldron may be used as the combining vessel, with the addition of a machine to produce an intimate admixture, and the minute redivision of the tallow. Figs. 507 and 508 will convey an idea of this apparatus. An upright shaft, A, Fig. 507, which may be of wood or iron, and from which arms, *a*, *a*, *a*, *a*, radiate to the sides of the caldron, is fixed permanently or temporarily in the copper. The mode of fixing and the material used, will depend on the nature of the caldron and the convenience of the manufacturer. An oscillating or rotatory motion is given to the shaft and connected arms by any of the ordinary methods of communicating motive power. If more convenient, a cylinder—Fig. 508—may be employed, with a shaft, C, passing through it horizontally, and from which arms, *c*,*c*,*c*,*c*,*c*,*c*, radiate, when a rotatory motion will thoroughly incorporate the fatty matter and the lie. For two and a half tons of tallow the cylinder should be about six feet in diameter and twelve feet in length. At D it must be provided with convenient doors for filling and discharging the materials. The caldron or cylinder having been charged with tallow, motion is communicated to the machine, and the lie is then gradually added. In a short time every particle of the fatty matter will be brought into contact with alkaline lie, and by such means saponification will be effected. The agitation must be continued for about three hours, or until the tallow appears to be completely saponified, which is known by the mass becoming thick, after which it is allowed to stand from one to four days, according to the quantity of the paste. When a cylinder is used in the above operation, the lie is run in, and motion communicated to the shaft immediately after the introduction of the tallow, the latter being only sufficiently heated to retain it in the fluid state, and the agitation is continued from three to four hours, or less if the tallow is perfectly saponified before its expiration. As the benefit of this process arises mainly from the saponification of the ordinary materials in a comparatively cold state, it is desirable that as soon as the mass thickens and the lie is absorbed, the cylinder should be emptied and the contents turned into an ordinary caldron, preparatory to being finished and converted into yellow soap by the addition of resin, or into mottled or white soap by the operation of finishing lies, according to the usual method. By this transfer from the cylinder to the caldron, time is allowed for the combination of the tallow and alkali to become perfect.

Fig. 507.

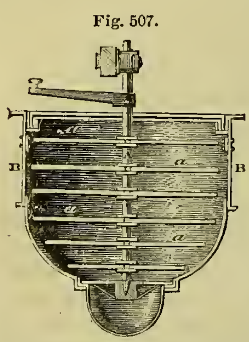
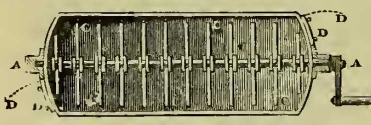


Fig. 508.



Another method for the manufacture of soap, according to the patentee more particularly applicable to palm-oil soap, was devised by Mr. Walterson of Manchester. The inventor claims for his process that a purer and more perfect soap is produced in a much shorter period of time than by the ordinary method, the soap being sufficiently hard for sale or use in the course of a few hours. His method consists in a mode of mixing or combining the oils or fatty matters employed with caustic soda, and in subsequently adding water for the purpose of converting such mixture or produce into soap. The ingredients used are animal or vegetal oil, either separately or mixed, caustic soda lie of 22° Twaddell, and water if possible free from any earthy or metallic impurity. The following description of the process applies more particularly to the production of palm-oil soap, and requires to be variably modified when other oils or fats are to be saponified. The quantity of bleached palm oil taken for one operation is seven hundred and eighty-four pounds; and after having melted this in a caldron, there is to be added gradually four hundred and seven pounds of caustic soda lie, testing 22° Twaddell, and the whole is carefully and thoroughly intermixed by agitation. The heat is then gradually increased, and the mixture constantly stirred, so as not to allow it to concrete on the bottom of the pan. After the operation has been continued three or four hours, the mixture assumes a whitish appearance, and by continuing the heat the aqueous portion is entirely evaporated, and the mass reduced to a perfectly dry state. The heat is now increased, and in a short time the mass again assumes the liquid form, and becomes of a brown color, which, according to the inventor, shows that combination with the alkali has been effected. The fire is then speedily withdrawn, and the agitation of the mass is continued as long as any fear of scorching is apprehended, after which the pan is left to become cool. The solid product of this operation is then to be broken up into powder, to which is afterwards added forty-five gallons of water, and the mixture is well agitated for about half an hour. Heat is then applied, and the contents of the pan raised to boiling, and kept so for about three hours, the stirring and agitation being continued during the whole period. As soon as the evaporation has been carried to the desired extent, and the soap appears of proper consistence, it is allowed slowly to cool. The contents of the pan, still in a liquid form, are then transferred to the ordinary frames, and left to cool and solidify, and in twenty-four hours the soap will be sufficiently hard to cut into bars. Soap prepared according to the above method, is never of so fine a color as that prepared by the old process from the same ingredients; besides which it is also less pure, as it contains of course all the saline impurities of the lie. The only advantage appears to be that the soap is finished in a much shorter period, but this, in the Editor's opinion, does not counterbalance the great disadvantages above mentioned.

Since the remission of the duty on soap, a process for its manufacture has been introduced by H. C. Jennings, but has not been adopted on a very considerable scale; for though it undoubtedly gives a purer and more perfect soap, the expense of production is much greater. In this method the oleaginous ingredient used is stearic or margaric acid as nearly pure as possible, and the alkali is derived from bicarbonates of potassa or soda; the fatty acids, possessing a decomposing power over these salts, render their previous caustization unnecessary. The fatty acids and solution of alkaline bicarbonate of specific gravity 1·500 are mixed in proper proportions, and heated at 212° until an intimate combination is obtained. The mass is then allowed to cool down to about 60°, and there is now added to each hundred pounds one pound of solution of ammonia of specific gravity ·880, and the same quantity of the strongest caustic potassa lie. These are to be added gradually, and well stirred with the soap until thoroughly mixed. The quantity of caustic alkali required to be added is greater or less in proportion to the state of purity of the fatty acids saponified. Lastly, the separation of the soap is effected in the usual manner by means of common salt or sulphate of soda. In the manufacture of yellow soap by the preceding method, there is added previously to the addition of caustic soda or potassa lie, fifteen to eighteen pounds per cent. of resin, first dissolved by boiling with a solution of pearl ash and common soda ash in equal proportions, so as to give a solution of specific gravity 1·800, while boiling hot. This is added to the solution of soap, and afterwards there is poured in a sufficient quantity of caustic lie to produce perfect saponification, and the soap is then separated as before. The Editor would especially recommend the above process of saponification for the production of the potassa soap ordered by the London Pharmacopœia. It is indeed the only method by which a perfectly pure potassa soap can be procured. This soap not being separable from its solutions, like soda soap, by salts of soda or potassa, as ordinarily prepared, is always contaminated by glycerin and other impurities.

In the manufacture of the variety known as GWYN and WILSON'S soap, the oils and fatty matters employed are heated with concentrated sulphuric acid, by which decomposition of the fats is effected, and glycerin eliminated, while the oily acids probably enter into combination with sulphuric acid. The fat so treated becomes much harder and less readily fusible, and is likewise rendered much more easily saponifiable, although it is true that not only a greater proportion of alkali is required, but the amount of product obtained is less than when the fat is saponified in the usual way. The following is the method of procedure as described by the inventors:—Ten tons of palm oil, whale oil, or other oily matter, are put into a wrought-iron vessel provided with a perforated steam worm, through which steam is admitted until the contents are heated to 350°. The fatty matter is then run into a tank formed of brick, lined with lead, and sunk into the ground. The tank is furnished with a pipe for the introduction of steam, but which does not terminate in a worm, as it would be liable to become choked by the sediment from the fat. The cover of the tank is made of wood, lined with sheet lead, and has two manholes closed by an oil joint about eight inches deep; through the cover a pipe passes connected with a high shaft, to allow the escape of offensive vapors. Two thousand pounds of concentrated sulphuric acid, specific gravity 1·80, are poured into the tank, the temperature of the mass being at the same time carefully watched by means of a thermometer immersed in it, and not allowed to exceed 350°. The heat is regulated partly by slackening the speed at which the acid is poured in, and partly by diminishing the quantity of steam admitted into the tank. The introduction of steam is continued throughout the operation; but as soon as the whole of the acid has been added, the fire employed for heating the steam is extinguished, and after that the steam continued for about four hours. The steam is heated after it leaves the boiler, by passing through pipes placed over a fire. At the expiration of four hours the steam is shut off, and a large pump introduced through a pipe in the cover of the tank; then as soon as vapors cease to be evolved, and the pump can be worked, the product is pumped into a wooden vessel, lined with lead, and provided with a steam worm. In this vessel the fatty matter is washed by means of free steam, with about half its bulk of water, for two hours, and then allowed twelve hours to separate.

TOILET SOAPS — SCENTED SOAPS. — The great variety of soaps thus designated, are usually prepared by remelting and clarifying white or curd soap, and adding various perfumes, colors, *et cetera*. These operations belong more properly to perfumery than to the soap manufacture; and their preparation has therefore been included in the article devoted to the consideration of this art, Vol. II., pages 676 to 679. Sometimes, however, since the remission of the soap duty in this country, the perfumer prepares soap directly by the cold process above described, and this is a more convenient method. The marbling of these soaps is produced by rubbing up the coloring material, such as vermilion, smalts, or ultramarine, with a little olive oil or soap, a small portion of which being taken on a palette knife, is pushed through the melted mass; thus the pink color of rose soap is produced by vermilion; blue by means of ultramarine; and brown by the addition of the various kinds of ochres and umbers. The cakes or tablets are formed by placing a soft mass of soap in a mould fixed in a lever press; the mould consists of a top and bottom die, fitting into a loose ring; by a sudden pressure the shapeless mass assumes the form of the ring, and is embossed on the top and bottom. Soap is ornamented with colored cameos by first forming the cake at a press, which makes a depression for the reception of the differently-colored soap, which latter is put in by hand, and the colored portion is embossed at a second press.

A very superior and beautiful marbled soap is manufactured by the Messrs. CROSFIELD of Warrington, Lancashire.

NAPLES SOAP.—This, so highly esteemed as a shaving soap, is said to be produced by saponifying mutton suet with lime, and then separating the fatty acids from the soap so formed by means of a mineral acid. These fatty acids are afterwards combined with caustic potassa by ebullition in the usual way. FAISZT, who examined Naples soap, gives the following as its composition centesimally:—

Fatty acids,	57·14
Potassa combined with fatty acids,	10·39
Sulphate of potassa, chloride of potassium, with a trace of carbonate of potassa,	4·22
Silica, *et cætera*,	0·46
Water,	27·68
Loss,	0 11
	100·00

Adulteration.—In the manufacture of soap certain substances are frequently added besides the fat, alkali, and water essential to its production. These additions cannot always be considered as sophistications, inasmuch as in some cases the quality of the soap is thereby greatly improved. Thus, in Dr. Normandy's patented process, the addition of a small proportion of fused sulphate of soda to an otherwise very soft soap, confers upon it a hardness which prevents its melting or dissolving too rapidly in the process of washing. Though it may be said that the manufacturer is, by such addition, enabled to use an inferior oil or fat, still no deception is practised, as the soap so produced is little inferior in detersive properties to the soaps of the better kinds of fat, while it may be purchased at a much lower price. Other additions are also frequently made. In those cases, however, in which the substance added rather improves than deteriorates the quality of the soap, it cannot be considered as a fraud. It is true that soap is extensively and fraudulently adulterated in the true sense of the term. The Editor would remark, however, that in his opinion the public craving for cheap goods has urged upon the makers the necessity of preparing soap at a low price; and as the simplest mode of doing so was to incorporate saline water with the curd, when in the act of solidifying in the frames, to the extent commensurate with the reduced price, this mode has been adopted. So far as this addition is concerned, it does not involve the character of the manufacturer or dealer; but when the addition of water is covertly made by the maker, and the article sold as a better quality, as is frequently done, at once the public is defrauded. In like manner, dealers are in the habit of purchasing soaps at cheap rates—soaps which are highly adulterated—with the view of disposing of them at prices which better qualities command. Here, again, the consumer bears the weight of the villany, whilst its guilt presses upon the dealer, and the maker even does not escape with impunity. Certainly the maker, and the maker only, can protect the public from fraud in the matter of soap. By making certain qualities of soaps with definite and invariable amounts of ingredients, the public would in a short time become so well acquainted with the quality of the article, that inferior kinds which the cupidity of some makers might induce them to utter, would rapidly meet with its condemnation. If, however, the consumers will always purchase in the cheapest market, and whatever be the price asked, will, if possible, obtain the article at a still lower rate, they must expect to be imposed upon.

Analysis.—Under this head the most important point to be considered is the proper amount of water in soaps. The proportion of water in mottled or marbled soap, should never exceed thirty to thirty-five per cent. It is indeed impossible to introduce an excess of water into the paste of mottled soap, since the mottling being due to the presence of sulphide of iron and other ferruginous compounds, held partly in solution and partly in a state of suspension, if the soap has not a certain retentiveness the insoluble iron compounds would precipitate, leaving the soap perfectly white. The admixture of water with mottled soap is, however, practised in another way, namely, by plunging the soap as taken from the frames into a solution of salt, when it may be made to absorb from eighty to eighty-five per cent. of water, and become so soft as to be kneaded easily between the fingers. Properly prepared white soap should contain from forty to forty-five per cent. of water. Frequently, however, the proportion amounts to fifty-five or sixty per cent., and cases have been known in which soaps, combined with from eighty-three to one hundred and fifty-four per cent. of water, have been sold. This is either added directly to the soap when run into the frames, or the soap is kept for some time in a solution of salt. The proportion of water is also sometimes increased by submitting the bars of soap to the action of high-pressure steam in tight chests or bins; also by boiling the soap in high-pressure coppers before *cleansing*.

The proportion of water contained in a sample of soap, may be most readily ascertained by treating a portion in a water or oil bath, until it ceases to lose in weight. Two ounces or more of the sample to be examined should be taken and reduced to small thin shavings. Of these, after carefully mixing together, one hundred grains are taken, placed in a small porcelain or platinum crucible, and dried by exposure in a water bath for a sufficient length of time. When the water is completely disengaged, that is, when after repeated trials the weight remains constant, the operation is at an end. The difference between the first and last weighing indicates the per centage of water present. As previously mentioned, marbled soap should not contain more than thirty to thirty-five; and white or yellow forty to forty-five per cent. of water. The amount of water contained in soap may also be estimated indirectly as follows:—From five hundred to a thousand grains of the sample are taken and dissolved in water. To the solution hydrochloric acid is added in excess. Decomposition of the soap ensues, the greasy matters rise to the surface, and must be collected on a weighed filter, and when well washed and dried, carefully weighed, deducting the counterpoise of the filter. The filtrate, together with the washings, is now evaporated to dryness, and, after carefully drying, the weight of the residue is taken. This latter contains the alkali in the form of chloride, every one hundred parts of which indicate fifty-three parts of soda, or sixty-three of potassa soap, according as the soap under examination is a hard or a soda soap, or a soft or potassa soap. The amount of greasy matter or alkali thus ascertained is subtracted from that of the soap taken, and the remainder expresses the proportion of water present. Mottled soap treated as above should yield of fatty acids sixty-four parts, of soda six parts, and thirty parts of water. White soap should give of fatty acids fifty parts, of soda four and a half parts, and of water forty-five and a half parts.

It is evident that if other substances are present than those indicated, the results obtained by the foregoing method will be to that extent inaccurate. In such cases the other method must be pursued, and if it is desired to estimate also the proportion of fatty acids and of alkali, special examinations must be made as will be explained presently. Whenever the object is solely the determination of the amount of water, the method by direct evaporation is the simplest and best. To ascertain the proportion of oil or fat in a given sample of soap, the following process is recommended by DUMAS:—

One hundred grains of the soap are taken and dissolved in four or five ounces of boiling water, and the solution is filtered. A sufficient quantity of dilute acid is added to effect neutralization, and afterwards a weighed portion of pure and dry white wax. The whole is then heated until the wax is liquefied, and has combined with or taken up the oil or fat liberated from the soap by the stronger acids. After allowing it to cool the cake of wax obtained is removed and weighed; the increase above the original weight of the wax indicates the proportion of fat, oil, or grease contained in the soap. If the fatty matter of the soap when liberated by the acid itself concretes on cooling, the addition of wax is unnecessary, as the fat may be weighed *per se.* The liquid decanted from the fat, or solidified wax, may afterwards be submitted to examination, to ascertain the nature and state of purity of the base. If this is intended, hydrochloric acid should be used for the liberation of the fat, and then the presence of potassa is immediately recognized by the production of the very characteristic yellow precipitate, on the addition of bichloride of platinum. To ascertain the nature of the fatty material, DUMAS directs the aqueous solution of the soap to be saturated with tartaric acid, the fatty acids to be collected, and their point of fusion carefully observed. It is a matter of great difficulty to determine the particular kind of fat or oil used in the production of the soap under examination; yet by the above method, it is possible at least to prove the identity of the fatty component; as, for instance, whether the soap is made from tallow or from oil, or whether it is of the same kind as the sample from which it may have been purchased. The odor evolved by the fatty acids at the moment of decomposition of the soap by a stronger acid, or that developed when the fatty matter so liberated is treated in a small porcelain dish, will often indicate the nature of the fatty substance employed in its production, or that at least which is present in the greatest proportion. According to NORMANDY, another test as to the quality of the soap is, that the fatty or oily acid should be readily and completely dissolved by hot alcohol. The estimation of the proportion of alkali contained in a sample of soap, is frequently a point of great difficulty. When only one alkali is present, the determination is most easily effected by means of a test acid, and the operation is performed exactly as directed in the estimation of the value of potassa, Vol. II., page 729. For hard or soda soaps in the absence of potassa, an acid is used of which each alkalimetrical division is equivalent to one grain of soda; and, therefore, when the amount of soap taken for the assay is one hundred grains, the number of measures of acid required to cteffe neutralization at once indicates the per centage amount of soda contained in the sample. Such an acid is prepared by adding to each measure of concentrated sulphuric acid of specific gravity 1·8 to 1·84 about nine measures of water, and mixing thoroughly by agitation. When the mixture has become cool, its exact strength is ascertained, as follows:—One hundred and seventy-one grains of pure and dry carbonate of soda are taken and dissolved in water, and the solution is heated. The alkalimeter shown in Fig. 422 is then filled up to the point marked 0° with the mixture of acid and water, and sufficient of the latter is then poured into the solution of carbonate of soda to effect neutralization. The exact point is determined by testing, from time to time, with slips of blue litmus paper; and when the latter is tinged of a slight red color, the addition of the acid is discontinued, and the number of measures employed is noted. If the whole of the hundred measures are required, the acid is of proper strength; but if any less number have been added, it is then necessary to add more water, so that a hundred divisions shall exactly neutralize the hundred and seventy-one grains of carbonate of soda, this quantity being equal to, and indeed containing, one hundred grains of pure soda. This dilution, it will be observed, may now be effected with the greatest ease; for if ninety measures are required, then to each ninety measures remaining must be added ten additional measures of water, and the quantity of the latter required to be added is, of course, greater or less in proportion to the quantity of dilute acid employed, so that one hundred divisions shall contain only as much real acid as was before contained in the number of measures used. The acid being prepared, one hundred grains of the soap to be examined are dissolved in hot water, and the solution is filtered. The alkalimeter having been filled with acid, the latter is then poured into the soap solution until exactly saturated. The number of measures required at once indicates the centesimal amount of soda present. For the estimation of the alkali in soft or potassa soaps, an acid is generally used of different strength to that indicated above. This acid is of such strength that one hundred measures represent one hundred grains of pure potassa. Full directions for its preparation will be found under POTASSA, Vol. II., page 730. The process of estimation is performed exactly in the same way as for hard soaps. The test acid for hard soap may also be used to determine the alkali in soft soaps, simply by allowing for the difference in the atomic weight of the two bases. In this case it is only necessary to calculate for every ten grains of alkali found, 15·16 grains of potassa.

In Germany, America, and some other countries, soda and potassa are frequently both used in the production of hard soap. The determination of the amount of alkali in such instances is much less easily performed. The most convenient process is as follows:—A hundred grains of the soap are taken and dissolved in water, as before, and the solution is exactly neutralized by means of the soda test acid. By a simple calculation one may then ascertain the quantity of dry sulphuric acid which it has been necessary to add, for in every hundred alkalimetrical divisions of acid are contained one hundred and twenty-nine grains of anhydrous sulphuric acid. The proportion of dry acid added being known, the solution is filtered to remove the liberated fatty acids, and the filtrate evaporated to dryness. The residue, consisting of the mixed sulphates of the alkalies, is then heated to redness, and after cooling, weighed. The weight of acid added, and that of the mixed sulphates being known, the relative proportion of each alkali contained in the soap may then be easily calculated; for as one hundred parts of sulphuric acid give 177·5 of sulphate of soda, and the same quantity of the acid gives 217·5 of sulphate of potassa, if the weight of the dry sulphate obtained exceeds the ratio 100 : 177·5, the excess is due to the salt of potassa, from which the proportion of pure potassa may now be ascertained, since eighty-seven parts of sulphate of potassa represent forty-seven of potassa.

The amount of foreign matters—that is, substances other than fatty matters, alkali, and water present in soap—is determined by taking a weighed portion, and after having reduced it to thin shavings, treating them with boiling alcohol. A white soap should dissolve completely, and a mottled soap should not leave more than one per cent. The exact amount of the residue is determined by weighing it; its nature is ascertained by treating it with cold water, by which the soluble salts are extracted, and the proportion of these is estimated by evaporating the liquor to dryness. The residue unaffected by the cold water, is then treated with boiling water. The presence of starch or fecula is now recognized by the appearance of a more or less thick gelatinous mash. The filtered solution, upon the addition of a little iodide of potassium and nitric acid, or a bubble of chlorine, if starch be present, becomes violet blue. The insolubility of the residue in either hot or cold water, denotes the presence of lime, clay, *et cetera.* If lime, it is readily soluble in hydrochloric acid, and upon the addition of ammonia and oxalate of ammonia to the solution, a white precipitate appears. What remains unaffected by alcohol, acid, and water, is clay, silica, pumice-stone, *et cetera.* The presence of an alkaline silicate in soap is detected by dissolving a portion in water, neutralizing by means of dilute hydrochloric acid; if the silicate is present in moderate quantity, silicic acid at once falls, and may be easily recognized. When it exists in lesser proportions the fatty acids should be removed by filtration, and the filtrate then evaporated to dryness, and the residue treated with water; if silica be present, it will remain as a white gritty powder, and may be collected, dried, ignited, and weighed.

It not unfrequently happens that a soap contains more or less uncombined or non-saponified fatty matters, and in this case, when the soap is dissolved in water, a film of oily matter is seen to float on the surface. Morfit gives a method for determining the amount of this as follows:—The aqueous solution is decomposed by means of hydrochloric acid, when the fatty acids as well as the unaltered fatty matter collect together on the surface of the liquid. These are separated by filtration, thoroughly washed, and then treated with caustic baryta. The precipitate produced is thrown on a filter, washed with boiling water, and then acted upon by hot alcohol. By this means, the non-saponified grease dissolved is from the soap of baryta, and after separation of the alcohol by evaporation, its weight may be ascertained. When tested by litmus paper, it should not show an acid reaction. In the appended table, the great discrepancies in the value of different kinds, of soap are clearly pointed out; yet it must be noticed that the portion of alkali in combination with the fatty acids was not separated in the analysis from that portion contained in a free state—for instance, as lie:—

Variety of Soap.	Fatty Acids.	Dry Potassa.	Dry Soda.	Water.	Common Salt	Analyst.
Castile soap; specific gravity 1·0705,	76·5	"	9·0	14·5	"	Ure.
Castile soap; specific gravity 0·9669,	75·2	"	10·5	14·3	"	"
Fine white toilet soap,	75·0	"	9·0	16·0	"	"
Ordinary white soap from Glasgow,	60·0	"	6·4	33·6	"	"
Mottled tallow soap of good quality, prepared from potassa after having been kept for several years,	81·25	1·77	8·55	8·43	"	Heeren.
Brown resin soap from Glasgow,	70·0	"	6·5	23·5	"	Ure.
London cocoa nut oil soap—marine soap,	22·0	"	4·5	73·5	"	"
Hard poppy oil soap,	76·0	"	7·0	17·0	"	"
French white soap,	50·2	"	4·6	45·2	"	Thenard.
Marseilles marbled soap,	64·0	"	6·0	30·0	"	D'Arcet.
Marseilles marbled soap,	60·0	"	6·0	34·0	"	"
White Marseilles soap,	68·4	"	10·24	21·36	"	Braconnot.
White Leipzig tallow soap,	76·3	8·8		14·7	"	Abendroth.
White Leipzig tallow soap,	50·0	9·4		29·8	"	"
Leipzig marbled soap,	45·0	9·8		38·0	"	"
Soap from hazel nut oil,	64·0	7·0		28·0	1·0	"
Soft soap,	44·0	9·5	"	46·5	"	Thenard.
London soft soap,	45·0	8·5	"	46·5	"	Ure.
Belgian soft or green soap,	36·0	7·0	"	57 0	"	"
Scotch soft soap,	47·0	8·0	"	45·0	"	"
Good green soap,	34·0	9·0	"	57·0	"	"
Scotch soft rape oil,	51·6	10·0	"	38·33	"	"
Scotch soft olive oil soap,	48·0	10·0	"	42·0	"	"
Semi-hard soap for fulling,	62·0	11·5	"	26·5	"	Verviers.
Ordinary soft soap, 1st sample,	44·0	9·5	"	46·5	"	Chevreul.
Ordinary soft soap, 2nd sample,	42·8	9·1	"	48·0	"	"
Ordinary soft soap, 3rd sample,	39·2	8·8	"	52·0	"	"

There are several other important considerations relating to the determination of the value of soaps, besides what is revealed by analysis. As KNAPP observes, the consumer should not be satisfied with a soap in which the amount of the dry fatty alkaline compound accords with the price, unless the soap fulfils another condition of equal importance. The problem to be solved by the soap boiler, is the production of an article from which no more is dissolved or washed away, when it is employed as a detergent, than is absolutely necessary for cleansing purposes. When this is not the case, much soap is uselessly wasted. This property of soap is carefully watched by the laundress; and for purposes of domestic economy, the quantity of soap employed is much more materially affected by it, than by the state of the articles to be cleansed. If the soap contain too much water, or its consistence be rendered too loose by reason of an excess of lie or salt disseminated through it, as is the case with many of the varieties of soap described, the waste from this cause will be proportionately great. On the contrary, if the soap is over dry, much laborious exertion will be required to detach a sufficient quantity for the purposes required. Curd soap is the only kind which maintains the proper mean between these two opposing characters, and this is due to the quantity of water which it contains, and its state of solidity. Soap that has become too dry, is improved by being kept in a moist place, and an opposite treatment improves soap that contains too much water. But, of course, as regards the foreign salts they contain, no alteration or improvement can take place. Curd soap is therefore the proper form in which soap should be sold; no deception need however be practised, when soap containing a large amount of water, as that from cocoa-nut oil is manufactured, provided a corresponding reduction be made in the price. The same applies to soap prepared from bones, fuller's earth, silica, *et cetera*, which, if they cannot positively be called adulterations, are very much calculated, like the former, to promote dishonest traffic. The production of these articles will find very little encouragement when the soap boilers understand their own interests and responsibilities. These remarks, of course, do not apply to soft soaps which are used for entirely different purposes, and in a different manner.

USES OF SOAP.—Soap is applied for washing, for fulling woollen cloths, *et cetera*, and in medicine. Its application for washing is founded on two conditions, namely, on its power to remove fatty matters from textile and other materials, and to form therewith an emulsive mass soluble in soapy water; and on the readiness with which the neutral salts of fatty acids are decomposed by warm water into acid compounds and free alkali. The latter acts upon the impurities of substances, and forms with them compounds partly soluble, and partly such as will no longer adhere to textile fabrics and other bodies, whilst the separated acid salts of the fatty acids keep the surface of the material in a smooth condition.

STATISTICS.—The manufacture of soap is carried on more extensively in the United Kingdom than in any other country of the world. The number of manufacturers has gradually decreased since the year 1801, when there were six hundred and twenty-four. In 1811 the number was five hundred and twenty-two; in 1845, three hundred and fifty-six; and in 1850, three hundred and twenty-nine, besides sixty-eight remelters or perfumers. But, notwithstanding this decrease in the number of makers, it is almost needless to say that the quantity of soap produced was greater each year, and since the remission of the duty, has increased in still greater proportion. The quantity made in Great Britain in 1850, amounted to ninety-one thousand two hundred and fifty-five tons. Of this quantity five thousand six hundred and five tons were exported to foreign parts, and there were therefore detained for home consumption eighty-five thousand six hundred and fifty tons. Of this ten thousand two hundred and four tons were consumed by manufacturers of woollens, silks, and cotton. After deducting the quantity exported, and that used by manufacturers, it appears that seventy-five thousand four hundred and forty-six tons were employed for domestic purposes in Great Britain, a quantity equivalent to eight pounds and one ounce to each person. In 1851 the quantity manufactured in Great Britain amounted to ninety-one thousand nine hundred and fifty-three tons. Of this quantity England produced eighty-one thousand five hundred and sixty-nine tons, and Scotland nine thousand nine hundred and eighty-four tons. In 1852 the quantity manufactured was ninety thousand six hundred and sixty tons. In England the quantity is made up, of *hard soap* seventy-five thousand three hundred and seventy-eight tons; of silicated soap, five hundred and ninety tons; and of *soft soap*, five thousand six hundred and one tons. The nine thousand nine hundred and eighty-four tons produced in Scotland, consisted, of *hard soap* six thousand seven hundred and eighty-eight tons; silicated soaps, three tons, and of *soft soap*, three thousand one hundred and ninety-three tons. The quantity imported into Great Britain in the above year, was—from foreign countries, one thousand five hundred and thirty-three hundredweight three quarters of Naples soap; from Ireland fifty-two tons seven hundredweight of hard soap, and twenty-seven hundredweight ten pounds of soft soap. The quantity of soap produced in the latter country cannot be ascertained, as there having been no duty levied upon it, no returns were required. The annual revenue derived from the soap manufacture in Great Britain in the last years the duty was levied, exceeded one million pounds sterling. It was entirely remitted in 1853.

The following, the Editor understands, are among the largest and best soap factories in the three kingdoms:—The West of England Soap Company, Plymouth; Mr. JOHN WHEEN, London; Messrs. TYSON and RICHMOND and Mr. WILLIAM MOORE, Liverpool; Messrs. WILKIE and SOAMES, East Greenwich, London; Messrs. J. BARRINGTON and SONS, Dublin; Messrs. HOWE and Company, Old Brentford; Messrs. CHARLES TENNANT and Sons, Glasgow, *et cetera*.

SODIUM.—*Sodium*, English and French; *Natrium*, German and Latin.—This is one of the metals discovered by SIR HUMPHREY DAVY, through the agency of voltaic electricity. Moistened hydrate of soda was employed, and the oxygen both of the water and of soda was liberated at the positive pole, and the sodium of the oxide at the negative pole.

About the same time, 1807, were discovered also potassium, barium, strontium, and calcium, and, besides, traces of metallization were also obtained from the earths. The compounds of sodium with other substances are of great importance in the arts and manufactures; for example, it enters into the composition of common salt, of sulphate of soda, and of the carbonates of soda—substances so important as articles of commerce, owing to their daily employment in domestic economy, in the manufacture of glass, of soaps, in bleaching, and in numerous processes of manufacture little less important. Sodium itself, too, has lately become of great interest, and its preparation, it may safely be predicted, is destined shortly to occupy a position amongst the useful arts scarcely less important than the extraction of iron from its ores. As a metal, owing to the great facility with which it becomes oxidised, it is never likely to be much employed; but it is this very property of rapid oxidation which has caused it to be applied in the liberation of other metals from their combinations; and, from the extreme cheapness of carbonate of soda, and the facility with which sodium may be obtained from this salt, it would be doubtless possible to procure it on the large scale at a price little, if at all, higher than that of zinc.

PREPARATION.—The processes already described for the production of potassium are applicable also, with slight modifications, for the preparation of sodium. The apparatus required is also of exactly the same description as in the case of potassium. The substances employed are either hydrated soda and iron, or carbonate of soda and charcoal. These are placed in a malleable iron bottle—those in which mercury is imported answer admirably—and heated to whiteness in a powerful wind furnace. The gas, which after some time makes its appearance, is conducted into a receiver of iron or copper containing mineral naphtha or rock oil, and which receiver is kept cold by surrounding it with cold water, which is frequently changed. It should, of course, be provided with a vent for the escape of the incondensable gases evolved during the decomposition. The operation is much more productive than in the case of potassium, owing to the fortunate circumstance that sodium does not combine with carbonic oxide.

It appears, nevertheless, that the decomposition either of hydrate of soda by metallic iron, or of carbonate of soda by charcoal, is effected with greater difficulty than is the case with the corresponding potassa salts. It appears also, that by mixing the soda or carbonate of soda with a little potassa or carbonate of potassa, the operation is effected with greater facility, but the metal obtained is then a brittle alloy of sodium and potassium. From this, however, the whole of the potassium may readily be separated by means of slow oxidation, without any considerable loss of sodium. To effect this, the alloy obtained is founded into plates, and placed in a large bottle; these are covered with naphtha, and the air in the bottle is occasionally removed. After a few days the whole of the potassium will have disappeared, and pure and very ductile sodium remains. The process usually employed in the preparation of sodium is that recommended by SCHOEDLER. The carbonate of soda used is obtained by the ignition of acetate of soda, free access of air being avoided. The object of this is to obtain the carbonate in a very pure state, since, if sulphate of soda be present, it becomes reduced in the process to sulphide of sodium, which acts strongly on the iron bottle. The mixture of carbonate of soda and charcoal obtained is to be mixed with a fourth of its weight of charcoal in fine powder, and with double this quantity of charcoal in a coarse state, to prevent fusion of the mass, which, should it occur, the fused contents spirt into the tube, and choke it up. This mixture, heated in the iron bottle, yields pure sodium, with very little black residue.

The proportion of sodium obtained by the author of this process was, from three pounds of the commercial acetate, about four and a half ounces of sodium; but in the laboratory at Giessen, even when it was obvious that the result was capable of considerable improvement, three pounds of acetate yielded nearly five ounces of sodium, the whole of the sodium present being about seven ounces. To remove the impurities from the globules of sodium, SCHOEDLER directs them to be pressed through strong and not very fine linen, the metal being first heated in naphtha to the boiling point.

PROPERTIES.—Sodium is of a silver white color; its lustre is more brilliant than that of lead, but scarcely equals that of silver. At the ordinary temperature it is solid, but soft and ductile like wax. At 4° it is rather hard, at 32° very ductile, at 120° it is semifluid, and at 194° perfectly so. Though less fusible than potassium, it is more readily volatile, and hence a less intense heat is required in its preparation. When exposed to the air it quickly becomes tarnished, owing to the formation of a crust of soda; and if heated nearly to redness, it inflames, and emits brilliant scintillations. The specific gravity of sodium is 0·972 at 60°, and it is consequently lighter than water, and if thrown into this liquid exposed to the air it swims about, presenting the appearance of a silvery-fused globule, constantly decreasing in size and producing a hissing noise, owing to the escape of hydrogen gas. These phenomena continue until the whole is dissolved as soda.

Potassium under the same circumstances takes fire, and continues to burn until dissolved; but sodium, in decomposing water, either produces less heat or requires a higher temperature to inflame it. If, however, the water be thickened with gum, so as to retard the movement of the sodium over the surface, or if there be only a few drops of water, the metal then ignites.

Sodium, like potassium, decomposes most oxides, metallic and non-metallic; also by far the greater number of salts, deoxidising not only the acid but the base also, if it happen to be oxide of a heavy metal. When thrown upon the surface of mercury, sodium forms an amalgam, with the production of heat and light; this does not take place with potassium. Sodium is employed in the arts, principally in the preparation of aluminium, by the decomposition of the chloride of that base.

OXIDE OF SODIUM.—SODA.—When sodium is burned in dry air or in oxygen a white powder is formed, which attracts moisture and carbonic acid from the atmosphere. This is the *protoxide* of sodium —Na O. It is very similar to the protoxide of potassium, but may be known from it by the following properties:—When exposed to the air at the ordinary temperature, it first attracts moisture, becomes liquid, and, after further exposure, again solidifies; the protoxide of potassium, however, always remains moist. The other oxides of sodium are the *suboxide*—Na_2 O —which is a greyish-white dull brittle mass, more combustible than the metal itself; and the *peroxide*, which is a dirty greenish-yellow substance, supposed to have the composition Na O_3, but, never having been obtained in the pure state, this of course has not been proved. Neither of the oxides of sodium *per se* have any application in the useful arts, but the combination of the protoxide with water, namely hydrate of soda, sometimes termed simply soda, and also known as caustic soda, is an article of very great importance. It was known probably at a very early period, though, up to the time of the discovery of the alkaline metals, this and the hydrate of potassa were regarded as anhydrous alkalies.

PREPARATION.—The hydrate of soda is usually obtained by decomposition of the carbonate, by means of quick or hydrate of lime. To a boiling solution of five and a half parts of crystallized carbonate of soda, in twenty parts of water, a quantity of milk of lime, prepared by treating one and a half parts of burnt lime with four parts of warm water, is added in small portions at a time, and the mixture is boiled, with the addition of more milk of lime, until the filtered solution ceases to effervesce on the addition of an acid. The decomposition is expounded in the annexed equation—

$$\underbrace{\mathrm{Na\,O,\,CO_2}}_{\text{Carbonate of soda.}} + \underbrace{\mathrm{Ca\,O,\,HO}}_{\text{Hydrate of lime.}} = \underbrace{\mathrm{Na\,O,\,HO}}_{\text{Hydrate of soda.}} + \underbrace{\mathrm{Ca\,O,\,CO_2}}_{\text{Carbonate of lime.}}$$

By evaporating the solution to dryness, a hydrate of soda is obtained, which, however, usually contains traces of silicic acid, aluminacic, and phosphoric acid. These impurities may be removed, except a minute trace of alumina, by treating the solid hydrate with alcohol, in which the soda salts of those acids are insoluble. In evaporating the alcoholic solution, it is necessary to add a little water from time to time to prevent blacking of the mass. Probably the purest hydrate of soda is procured by decomposing the pure sulphate by means of hydrate of baryta. The soda salt being dissolved in water, the hydrate of baryta, also in solution, is added as long as precipitation ensues. The clear solution decanted from the precipitate and carefully evaporated to dryness, yields a mass of hydrate of soda perfectly free even from alumina.

PROPERTIES.—Hydrate of soda is a white opaque brittle substance, of a fibrous texture; it fuses below redness. In properties, it greatly resembles the corresponding salt of potassa, but is less volatile at a red heat than this salt. When exposed to the air it rapidly attracts moisture, becomes liquid, but soon dries up again; the mass becoming converted into carbonate, which, unlike the carbonate of potassa, is not deliquescent. A solution of hydrate of soda, which is very caustic and powerfully alkaline, dissolves wood, hair, the skin, and most animal matters; tallow and other unctuous substances, with formation of soaps; sulphur, and some metallic sulphides; silicia, alumina, and several metallic oxides quite insoluble in water.

The following table, constructed by ZIMMERMAN, shows the quantity of soda—Na O—in alkaline menstrua at different densities:—

QUANTITIES OF SODA IN A SOLUTION OF SODA AT 15° CENTIGRADE—59° FAHR.—BY ZIMMERMAN.

Specific gravity.	Per cent soda	Specific gravity.	Per cent. soda
1·4285	30·220	1·2392	15·110
1·4193	29·616	1·2280	14·506
1·4101	29·011	1·2176	13·901
1·4011	28·407	1·2058	13·297
1·3923	27·802	1·1948	12·692
1·3836	27·200	1·1841	12·088
1·3751	26·594	1·1734	11·484
1·3668	25·989	1·1630	10·879
1·3586	25·385	1·1528	10·275
1·3505	24·780	1·1428	9·670
1·3426	24·176	1·1330	9·066
1·3349	23·572	1·1233	8·462
1·3273	22·967	1·1137	7·857
1·3198	22·363	1·1042	7·253
1·3143	21·894	1·0948	6·648
1·3125	21·758	1·0855	6·044
1·3053	21·154	1·0764	5·440
1·2982	20·550	1·0675	4·835
1·2912	19·945	1·0587	4·231
1·2843	19·341	1·0500	3·626
1·2775	18·730	1·0414	3·022
1·2708	18·132	1·0330	2·418
1·2642	17·528	1·0246	1·813
1·2578	16·923	1·0163	1·209
1·2515	16·319	1·0081	0·604
1·2453	15·714	1·0040	0·302

Solution of caustic soda constitutes the soda lie of the soap manufacturer, and is usually prepared on the spot by decomposing carbonate of soda or *soda ash* by means of lime. The mixture is placed in large cast-iron vats and covered with water, and after some hours the lie is withdrawn through a plug at the bottom of the vat, and either fresh water or a weak lie introduced at top. Full directions for the proper performance of the process are given under the article SOAP.

The solution of soda so prepared is contaminated with the common salt, sulphate of soda, and other constituents of soda ash; these may, however, be separated in great part by concentrating the solution considerably, these salts being insoluble in a strong solution of soda. A very useful article has lately been introduced by some alkali manufacturers, intended to supersede the use of the soda ash in the soap manufacture, and in other processes of fabrication in which caustic alkali is employed; and considering the advantages likely to ensue on its introduction, and the great simplicity of the process of production, it is a matter of surprise that its preparation on the large scale has been so long delayed. The article in question is a very pure solid caustic soda, containing hydrate of soda to the amount of nearly eighty per cent.

Probably the oldest method of producing caustic soda on the large scale, though it was applied as a preliminary to the preparation of the carbonate of soda, is that originally discovered by Scheele. It consists in the decomposition of chloride of sodium by means of protoxide of lead or litharge. This method was employed in England by Mr. Turner, and in France by Chaptal and Berard, for producing, besides caustic soda, the fine yellow pigment designated *patent yellow*; the operation was performed by intimately mixing and rubbing together one part of salt and from four to six parts of litharge, and a little water. Double decomposition takes place between the salt and a portion of the oxide of lead, with formation of caustic soda and chloride of lead, as shown in the annexed equation:—

$$\underbrace{Na\,Cl}_{\text{Chloride of sodium.}} + \underbrace{Pb\,O}_{\text{Oxide of lead.}} = \underbrace{Na\,O}_{\text{Soda.}} + \underbrace{Pb\,Cl}_{\text{Chloride of lead.}}$$

The latter salt afterwards unites with a portion of undecomposed oxide of lead, and remains as an insoluble oxychloride of lead. About twenty-four hours are required to complete the decomposition, during which time the mixture is to be constantly agitated. It is then allowed to stand a few hours to settle, and the solution of caustic soda is then decanted, the residue well washed with successive portions of water, the washings being used in the preparation of a fresh quantity. The decanted solution on evaporation yields a very pure hydrate of soda, and the lead compound, after being dried and fused, becomes of a beautiful yellow hue. The decomposition of the common salt is in this process very complete; but owing to the high price of litharge, and the limited sale of the pigment, the method has been generally abandoned as a manufacturing process.

The attention of manufacturers was first directed in 1853, by Mr. Gossage, to a source of caustic soda, from which it may be obtained with great economy and by a very simple method. This source is the liquor obtained by lixiviation of black ash or ball soda, a compound which will hereafter be minutely described. The chief object of the manufacture, of which black ash is an intermediate product, is the preparation of carbonate of soda—that salt which is contained in the largest proportion in black ash liquors—and one of the principal advantages of this method of procuring caustic soda, is that by its separation from black-ash liquors, the carbonate is obtained in a considerably pure condition. The liquor resulting from the lixiviation of black ash contains carbonate of soda, sulphate of soda, and caustic or hydrate of soda, chloride of sodium—a deep-reddish compound of sulphide of sodium—and a few other substances, in very minute quantities. When the menstruum is concentrated by boiling, crystals of monohydrated carbonate of soda separate; and if the evaporation be continued the whole of the carbonate falls in this state and can be readily separated, leaving a reddish or sometimes a blackish lie, the principal constituent of which is caustic soda. On further concentrating this mother-lie to a certain point, and adding an oxidising agent, the double sulphide of sodium and iron is decomposed, and the solution loses its deep color; any sulphates or other compounds which separate during the concentration are removed; and there remains a liquor, which in boiling to the necessary degree, affords an almost perfectly white solid hydrate of soda, contaminated with only a very small proportion of other matters. In Gossage's specification, which will be alluded to more in detail in connection with the improvements in the manufacture of *soda ash*, he directs the black-ash liquor first to be exposed to the air, so as to absorb oxygen therefrom, the effect of which is to destroy a great proportion of the double sulphide contained in such lie, and, consequently, the removal of much of the coloring matter. To the menstruum so purified he gradually adds a solution of chloroxide of calcium or bleaching powder, in order to convert any hyposulphite of soda which may be present into a sulphite or sulphate of soda; he then concentrates the liquor by evaporation, and removes the whole, or nearly the whole, of the carbonate of soda and other salts, and afterwards continues the evaporation till, on cooling, a solid mass of hydrate of soda is obtained.

Prepared according to the directions given above, the caustic soda is still very highly colored, and would certainly be objected to by most consumers of this article. By a modification of the process, however, the hydrate may be obtained white, or with only the slightest possible tint; and this improved process is now generally employed by alkali manufacturers. The liquor, after the separation of the greater portion of the carbonate of soda, is conveyed to an iron boat-shaped pan, and further concentrated to remove the remainder of the salts present. Whilst the liquor is in a state of ebullition in this pan, and at a density of 1·50, nitrate of soda is added in sufficient quantity to effect the decoloration of the fluid; this salt yields oxygen to the sulphide, and converts it into sulphite, in which the sulphide of iron is insoluble; whilst its nitrogen is liberated in the form of ammonia, and the base is set free in the fluid. Thus—

$$\underbrace{Na\,S}_{\text{Sulphide of sodium.}} + \underbrace{Na\,O,\,S_2\,O_2}_{\text{Hyposulphite of soda}} + \underbrace{Na\,O,\,SO_2}_{\text{Sulphite of soda.}} + \underbrace{Na\,O,\,NO_5}_{\text{Nitrate of soda.}} + \underbrace{4\,HO}_{\text{Water.}} = \underbrace{4\,(Na\,O,\,SO_3)}_{\text{Sulphate of soda.}} + \underbrace{NH_4\,O}_{\text{Ammonia.}}$$

or

$$\underbrace{2\,(Na\,S)}_{\text{Sulphide of sodium.}} + \underbrace{2\,(Na\,O,\,S_2\,O_2)}_{\text{Hyposulphite of soda,}} + \underbrace{Na\,O,\,NO_5}_{\text{Nitrate of soda,}} + \underbrace{4\,HO}_{\text{Water,}} = \underbrace{4\,Na\,O,\,SO_2}_{\text{Sulphite of soda.}} + \underbrace{NH_4\,O}_{\text{Ammonia}}$$

The liquor is drawn off from the forementioned pan after the salts have deposited, which happens in a period of four hours' repose, and transferred to another pan or pot, and the evaporation continued till the liquid readily solidifies on cooling. From half to one hundredweight of the nitrate of soda is sufficient to purify such a quantity of liquor as will yield one ton of caustic soda.

A process in which caustic soda is produced was patented some years ago by Mr. William Hunt, the principles of which were briefly as follows:—When the product of the decomposition of sulphate of soda by coal or coke is lixiviated with water, and the solution which contains sulphide and bisulphide of sodium with caustic and carbonate of soda, is boiled with oxide of zinc or black oxide of copper, double decomposition ensues between the sulphide of sodium and the oxide of copper or zinc, and sulphide of either of the metals results, with caustic soda in the solution. The metallic sulphide thus produced is made available in the preparation of another quantity of sulphate of soda from common salt, by a process which will be described in treating of the preparation of sulphate of soda. It has been proposed also to procure caustic soda directly from the sulphate, by decomposing this salt by means of a solution of hydrate of baryta. When a solution of sulphate of soda is mixed with one of caustic baryta, changes ensue as in the annexed equation:—

$$\underbrace{\mathrm{Na\,O\,SO_3}}_{\text{Sulphate of soda,}} + \underbrace{\mathrm{Ba\,O,\,HO}}_{\text{Hydrate of baryta,}} = \underbrace{\mathrm{Na\,O,\,HO}}_{\text{Hydrate of soda,}} + \underbrace{\mathrm{Ba\,O\,SO_3}}_{\text{Sulphate of baryta.}}$$

Sulphate of baryta is insoluble; and, therefore, if the mixture be made in proper proportion, nothing remains in the solution but caustic soda. The difficulty of procuring with facility the requisite quantity of caustic baryta, will probably always prevent this process from becoming general. The process for the production of caustic soda on the large scale from black-ash liquors is so convenient and economical, that it will probably be never entirely superseded. If there be a demand for greater quantities than can be obtained from this source, the carbonate of soda in black-ash liquors must be converted into caustic soda by the addition of lime, and the caustic soda then separated as previously described.

Caustic soda is indeed now produced on a very lare scale; and from a consideration of the advantages likely to ensue, as its use becomes more general amongst manufacturers requiring alkali, a very great increase on the present demand may certainly be expected. It is to the soap manufacturer that the introduction of this salt will prove to be the greatest stimulus the trade has received since the introduction of artificial soda; indeed, the soap manufacture will be so greatly simplified by the use of this salt, that the present mode of production may be expected in a short time to be entirely abandoned.

CHLORIDE OF SODIUM—*Common Salt, Sea Salt, Muriate of Soda; Chlorure de Sodium*, French; *Kochsalz*, German.—This substance possesses a peculiar interest, from its being one of the usual and necessary constituents of food; whilst the enormous consumption in the arts, and the variety of purposes to which it is applied in manufacturing operations, invest the study with an importance second to none. Salt is the longest known compound of sodium. As early as the time of the destruction of Sodom and Gomorrah mention is made of it in connection with the judgment against LOT'S wife, *and she became a pillar of salt* In Leviticus it is alluded to as a preservative and a component of the prescribed sacrifice. In the gospels of the New Testament its preservative qualities are beautifully inferred from CHRIST'S testimony and charge to the Apostles—*Ye are the salt of the earth, but if the salt lose its savor wherewith will it be salted.* Salt, it is said, appears in the sacred volume as the emblem of eternity, of repentance, of reconciliation, and of wisdom. NUMA among the Etruscans, and PYTHAGORAS among the Greeks, repeated the precept of MOSES—*Do not speak of Deity without fire; nor sacrifice without salt.* PYTHAGORAS calls it *a substance dear to the gods;* HOMER designates it *divine;* and PLUTARCH remarks, *it symbolizes the soul.* Salt has always been, and is now, with the Arabs, the emblem of hospitality. It figures largely in Eastern story. A thief, for instance, entering an Arab's tent at night while the master is asleep, seizes some food and becomes aware of the flavor of salt; bound involuntarily by the laws of hospitality, he withdraws, without carrying out his felonious intention. In the story of the Forty Thieves, the chief robber, who enters the house of MORGIANA'S master on a false pretence, is enjoined to make such excuses whenever his host offers him salt as will enable him to refuse partaking of it without suspicion.

It would be interesting if one could learn the secret of the strange yearning mankind has for salt, which ages have not diminished nor civilization annihilated. Chloride of sodium occurs in every part of the human frame. It is organized in the solids and dissolved in the fluids; it creeps into every corner of the body, and plays a part in all the complicated processes of life, without which the machinery would be arrested in its operation. In England and America, the quantity of salt consumed gives twenty pounds per annum to each person; in France the average ranges about fifteen pounds; but in some countries the love of salt amounts to a mania. In Abyssinia every man carries a lump of salt; and when he meets a friend, he offers it to him to lick. Its use may be said to be almost as universal as water, and it may safely be regarded as among the most abundant mineral compounds in nature; certainly of all the minerals eaten, none can claim so high a place in science, history, and literature, and in the kitchen it is an indispensable condiment—

> Even cooks would deem't a grievous fault,
> Were viands eaten without salt.

When pure, chloride of sodium consists, in one hundred parts, of 59·67 chlorine and 40·33 sodium. It crystallizes generally in the form of the cube, the crystals usually being very perfect. It may, however, under particular circumstances be made to assume other shapes, but all closely allied to the cube. When a saturated solution in water is slowly evaporated, and the surface of the fluid kept perfectly still, the crystals as they form sometimes assume a very remarkable appearance. A cubical crystal first forms on the surface; other crystals as they grow attach themselves to the edges of the upper faces; the middle cube then sinks below the surface of the liquid, but is still held up by the lateral crystals, and the process goes on until a hollow square pyramid of considerable size, having its apex downwards, may thus be produced.

Chloride of sodium is only slightly more soluble in boiling water than in cold; according to POGGIALE :—

100 parts water	at 32°	dissolve	35·52	of salt.
"	" 57·2°	"	35·87	"
"	" 212°	"	36·61	"
"	" 229·46°	"	40·35	"

The last is the temperature of a boiling saturated solution of common salt, which will therefore deposit very little salt on being allowed to cool; but if there be some chloride of calcium or of magnesium present, the solubility of common salt at a high temperature rapidly increases, and a considerable crop of crystals of chloride of sodium may be obtained on cooling.

Common salt decrepitates when suddenly heated, owing to a small quantity of water becoming inclosed between the plates of the crystal, and its sudden expansion at a high temperature causing a fracture of the crystal. It melts at a low red heat, and may readily be volatilized in a hot furnace. The specific gravity of pure salt is 2·557. It has an agreeable and saline taste, and is slightly deliquescent in moist air.

There are two varieties of common salt in commerce —rock-salt, and the salt produced by the purification and evaporation of salt brines. Of the latter there are in England three qualities, differing not so much in their freedom from impurities as in the size of the crystals adapting them for special purposes in the arts.

ROCK-SALT.—*Native Salt*, *Mineral Salt*, *Sal Gem.* —Rock-salt occurs as a regular mineral deposit associated with gypsum; its position is properly within the new red sandstone, but it has been met with in other situations. It occurs in layers varying in thickness from a few inches to several hundred feet. The rock is usually of a reddish-brown tint, and is rarely found colorless. The cleavage is cubical. Salt beds usually appear to have been formed by the evaporation of inland seas, the salt as it accumulated gradually filling up the bed of the sea or lake. The limited extent of these deposits, as compared with the stratified rocks over and under them, would seem to imply this. Indeed there are several instances of this kind of deposit in process of formation in various parts of the world. Thus the bed of the Dead Sea is gradually being filled up with such a deposit, and a leaden plummet dropped in deep water will bring up with it crystals of remarkable size and beauty, and at the same time almost chemically pure; but there are several lakes distributed over the globe in which the water is either quite or very nearly saturated with salt. In Asia and Africa there exist basins of sand, from which salt water has evidently been removed by evaporation, leaving the bed of the basin covered to some depth with salt; indeed, in the neighborhood of the Red Sea, and Salt Lake in Western America, every considerable depression of the soil is more or less incrusted with salt. The mines of rock-salt, most probably originating in the manner described, are not found at any determinate elevation. Thus, the great deposit extending from Upper Austria through Saltzburg, is found at an elevation exceeding three thousand feet above the level of the sea; the saline rock of Arbonne in Savoy is seven thousand two hundred feet above sea level; and the immense accumulation in the Saletres of Peru, where the salt is associated with nitrate of soda, three thousand feet; while that in Wieliczka in Poland is eight hundred and sixty feet below sea level. All these beds, like other mineral deposits, are intersected by faults, and broken up by the upheaving and subsiding of the earth; but from their limited extent, the continuity of the bed is less frequently observed to be affected.

The great deposit of rock-salt that furnishes most of the salt used in England exists in Cheshire. The broad valley extending from near Malpas to Congleton, sweeping in the form of a crescent between the red-sandstone hills of Shropshire and the Staffordshire coal field on the one side, and the high ground of the Peckforton hills and Delamere range on the other, appears to be occupied by the saliferous and gypsiferous beds, lying as it were in a trough, to which the adjoining portions of both the above ranges dip. There are several faults and dislocations in this field; thus, at Lawton, rock-salt is found two hundred and ninety feet above sea level, while at Winsford it occurs ninety feet below, and at Frodsham Bridge no salt was found at four hundred and fifty feet below sea level. The continuity of the bed is frequently broken in the course given; and perhaps the number and depth of borings might to some appear insufficient to establish the extent of the bed; but the existence of the rock where it has not actually been reached, is ascertained with equal certainty by the peculiar sinking of the overlying ground, due to the withdrawal of the brine. The gypsiferous and saliferous beds at Northwich and Middlewich, where alone one has satisfactory information respecting them, may be estimated to be on an average seven hundred feet thick. The rock-salt lies in two beds principally. The depth to the first bed at Northwich varies with the undulations of the land, and also slightly with the irregularity of the bed itself, from ninety-six to one hundred and fifty-nine feet. At Winsford the depth is one hundred and eighty-nine feet. The thickness of the upper bed varies at Northwich from eighty-four to ninety feet in the pits sunk to the north-west, decreasing near the east border to eighty-one feet. It thins off towards the south-west, losing fifteen feet in thickness in the course of a mile. Below this lies a bed of indurated clay, thirty feet in thickness, and containing several thin veins of salt, and this overlies the second or great bed. At a pit at Marston, to the North of Northwich, this has been ascertained to be ninety-six feet thick. At Winsford, however, it is two hundred and twenty-five feet thick. At Northwich, the first sixty to seventy-five feet of rock are impure, the salt being contaminated with much clay and bituminous matter, in the next twelve or fifteen feet the salt is much clearer, and this portion only is worked. The clear portion corresponding to this is worked at Winsford at a depth of two hundred and ten feet in the rock.

The mining operations concerned in the getting of rock-salt hardly require any description. A shaft like that of a coal pit is sunk to such a depth as the position of the rock necessitates, and galleries are worked out from this. The rock is broken down by blasting, beginning at the top of the working and proceeding downwards. But little skill is required in supporting the roof from sinking in upon the miners, the rock being so hard and firm that the galleries are worked from sixty to eighty feet broad without danger. As the rock gives off no gases injurious to animal life in any quantity, the usual great difficulty of ventilating the mines becomes easy; and sometimes the motion communicated to the air by the descent and ascent of the bucket in which the salt is wound up from the pit, is all the ventilation supplied for some months in the year.

Salt is, however, seldom found in mining operations of sufficient purity to be used in the arts, without being previously submitted to some process of purification. A pure and colorless salt is met with sometimes at Cardona in Catalonia, and in the mines of Wieliczka; and this is, therefore, simply cut into a convenient shape for the market. But most of the rock-salt mined is of a reddish hue, and contains a very small proportion of marl, a little bitumen, and a red coloring matter, analogous in character to the red fungous growth that appears on crystals of salt produced by the slow evaporation of sea-water. In addition to these impurities, rock-salt contains small quantities of various other salts, which impart to it a bitter taste, and make it deliquescent; among these are sulphate of soda and sulphate of magnesia, chloride of magnesium and chloride of calcium. But although rock-salt contains these impurities, it is a curious fact that the more deliquescent of these *are not contained in the rock as solid bodies*, but as saturated solutions in water inclosed in very minute cavities of the crystal.

Rock-salt from various mines is frequently observed to contain, pent up within its substance, a quantity of gas in a state of great compression. This phenomenon has been noticed in the rock from Wieliczka to a remarkable extent. In dissolving this salt in water a crepitation is heard, and this is occasioned by the sudden fracture of the walls of the crystal, when the gradual process of solution has reduced them so far that they are no longer capable of resisting the pressure of the inclosed gas. The gas evolved has been examined by M. Dumas, and found to be nearly pure hydrogen. This gas may sometimes be heard blowing out in a mine like the light carbide of hydrogen of the coal mines; the quantity, however, is small, and it does not appear that an explosion has ever ensued from the incautious use of a candle.

It was customary to purify rock-salt in England formerly; but at present, salt brines of great purity and strength, and in unlimited quantity, may be obtained at so little cost, that recourse is now seldom had to the solution and subsequent evaporation of the rock. There is, therefore, little use for it, and most of the rock mined is exported. The quantity carried on the river Weaver, according to R. Hunt's report, from the 5th April, 1857, to 5th April, 1858, amounted to sixty-five thousand seven hundred and seventy-three tons.

There exists a large field of salt in Worcestershire, of which the principal bed lies three hundred feet below the surface of the ground; but the rock itself is not worked, and owing to a deficiency of borings, the geological characters of the deposit have not been so thoroughly studied as is the case with the Cheshire field. The whole of the salt prepared in the county is made by the evaporation of strong brines.

There is no country so favored in respect to the abundance and ease with which common salt may be procured as is England; and as this substance is a necessary of life, it sometimes happens that it becomes requisite in countries not so favored, to carry on the manufacture by the evaporation of very weak brines, and even of sea-water.

The following analysis may be considered to be the mean composition of the water of the ocean :—

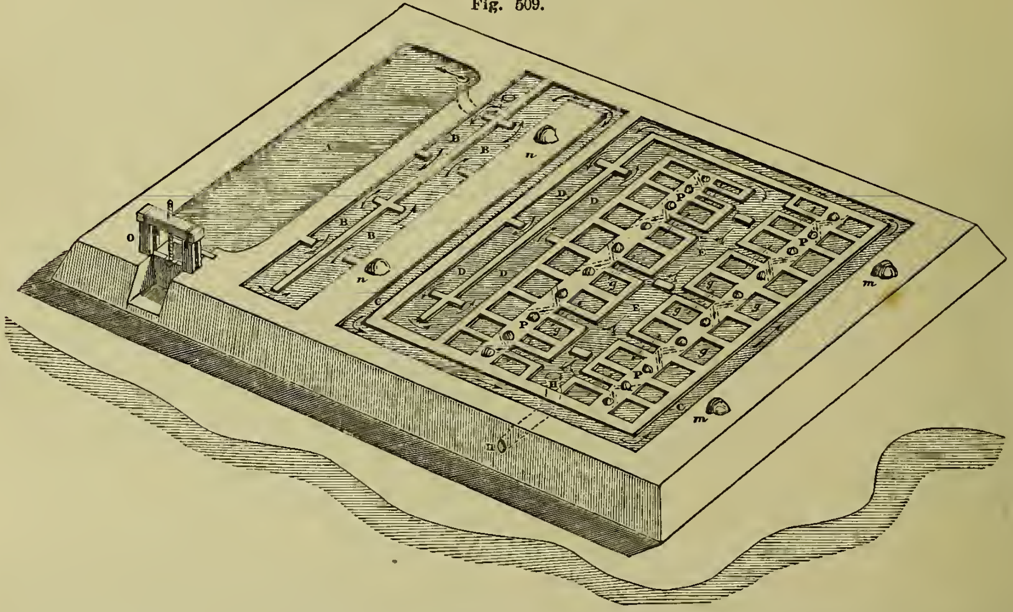
ANALYSIS OF SEA-WATER.

Water,	96·470
Chloride of sodium,	2·700
Chloride of potassium,	0.070
Chloride of magnesium,	0·360
Sulphate of magnesia,	0·230
Sulphate of lime,	0·140
Carbonate of lime,	0·003
Bromide of magnesium,	0·002
Iodides, *et cetera*,	0·025
	100·000

Obtaining Salt from Sea-Water.—In consequence of the small proportion of salt existing in sea-water, direct evaporation by means of fuel is never had recourse to in the preparation of common salt from this source. Slight variations are observed in the results obtained by various chemists as to the actual amount of salt in sea-water; but these discrepancies are most probably due to the influence of local causes and climate. The actual amount in the water of the Mediterranean is 2·7 per cent., as near as possible. Sea-water is always brought to a certain degree of concentration by placing it under such circumstances that it shall be most favorably affected by the drying influence of the atmosphere; and, as will be readily understood, the actual method of proceeding will vary greatly in accordance with the character, the climate, and the actual position of the works. Thus, in the South, where evaporation is rapid and the condition of the soil favorable, the sea, at the rising of the tide, is allowed to run through sluice-gates into a pond covering about an acre or more of ground, and about six feet deep. When full the gates are closed, and the water gradually deposits all the mud and matters in suspension. From this reservoir the clear water is conducted by pipes into a series of shallow basins, the whole covering some acres of ground, where, by exposing a very large surface of water to the drying influence of the sun and air, it rapidly evaporates. These basins are so arranged that the water shall flow slowly from the first reservoir downwards through the whole series, and the flow so regulated, that by the time the water arrives towards the last basins, it shall be in such a state of concentration as to deposit crystals of salt. A certain redness appearing on the surface, due to a fungous growth, is a good indication of the degree of concentration of the liquors, and its appearance is accompanied by the crystallization of the salt. The crystals as they fall are raked out at certain intervals and collected in small heaps on the ledges separating the basins one from the other. As soon as the mother-liquors begin to deposit salts of magnesia and sulphate of soda, they are run away into the sea, or they are allowed to flow into another series of evaporating ponds, to be there treated in such a way as to separate the sulphate of soda and other salts contained in sea-water from the common salt still remaining in them.

The manufacturing process will be best seen by a reference to the woodcut—Fig. 509. A is the large reservoir into which the sea is allowed to flow at high tide through the gate, O. From this it flows through a pipe into the long canal, B B C. The flow of water is very slow, and is regulated by means of the supply pipes. The sea-water then enters the reservoirs, D D, in which the water assumes a green tint, due to the growth of conferva ; these die, however, when the brine attains a specific gravity above 1·040. From the reservoirs, D D, the brine flows through the channel, E E, into the divisions, where it deposits a considerable quantity of sulphate of lime; this takes place when the brine is of a specific gravity between 1·116 and 1·145, and when it attains a specific gravity of 1·210 it no longer contains a trace of sulphate of lime —this salt being insoluble in a solution containing much sulphate of magnesia. The brine is now let into the compartments, *g g*, where it begins to deposit common salt. The depth of liquid on these beds is not much above two or three inches, and is renewed every two or three days, according to the state of the weather. The brine is allowed to concentrate until it attains a density of 1·263, when, although the whole of the common salt has not been removed from it, the liquors are allowed to run out on the crystallizing *tables* as they are called. The salt as it deposits forms a hard incrustation on these tables, which, during the five or six months the operation is conducted, attains a thickness of about three inches. The mother-liquors are now run off the tables, and the salt scraped up and collected into small heaps, P P, to drain. These are collected together into larger heaps, *m*, *n*, and covered with straw in the form of a haystack to protect them from the rain. They are then allowed to remain for some time, that the moisture of the atmosphere may gradually remove the more deliquescent salts, consisting of the chlorides of magnesium and calcium.

Fig. 509.



The product obtained in the manner describ3d is contaminated with clay from the bottom of the ponds, and it therefore requires to be purified by dissolving it in water, separating the clay by subsidence, and evaporating the solution to dryness. The manufacture of common salt on the plan described is carried on only during the summer months, that is, from March to September. The value of the process, of course, altogether depends upon the state of the atmosphere, and it frequently happens that a continued moist condition of this altogether arrests the evaporation.

The manufacture of salt, as described, is extensively carried on in France and Spain, and all parts bordering on the Mediterranean, and was formerly practised in England, particularly at Lymington in Hants.

In Russia, salt is manufactured by allowing sea-wate to freeze, and removing the ice as it forms. The success of this process depends upon the fact, that when sea-water partially freezes, the ice formed contains proportionately less salt than the remaining water; the mother-liquor, therefore, by repeating this process of congelation, becomes more and more impregnated with salt, until, indeed, a saturated solution of brine may in this way be formed.

Dr. WALKER, from experiments made in the Polar Seas, found that at 28·5° sea-water begins to freeze, and as the process of congelation went on he observed a saline *efflorescence* to form on the surface of the ice; but when the ice had attained a considerable thickness this efflorescence was not observed to increase, and Dr. WALKER concludes that the excess of the salt was then precipitated. It may be remarked that, according to Dr. KANE, if the cold be sufficiently intense, the water produced by melting the ice will be so far free from salt as to be fit to drink. In Dr. WALKER's experiments, however, the purest specimen of water obtained by melting the ice formed at 42° was of specific gravity 1·005, and afforded abundant evidence of the presence of common salt, and in quantity sufficient to make the water unfit for most domestic purposes. The salt obtained by the evaporation of the mother-liquors, as described, is however very impure, containing many of the foreign salts present in sea-water, as will be seen from the analysis as under:—

ANALYSIS OF SPECIMENS OF RUSSIAN SALT PRODUCED BY THE FREEZING PROCESS.

	Salt from			
	The Sea of Okhotsk.	Salt works at Oustkout.	Salt works at Irkoustk.	Salt works at Soleuginsk.
Chloride of sodium, ...	77·60	74·84	91·49	74·71
Chloride of aluminium,...............	6·20	1·17	2·60	6·50
Chloride of calcium, ...	0·94	5·21	1·10	1·44
Chloride of magnesium...............	1·66	3·57	2·05	3·55
Sulphate of soda, ...	13·60	15·20	2·76	13·80
	100·00	100·00	100·00	100·00

The salt obtained would have been of much better quality if such a quantity of milk of lime had been added to the concentrated mother-liquors as would have been sufficient to carry down the sulphuric acid, and to decompose the chlorides of calcium and of aluminium.

SALT SPRINGS AND WELLS—*Brines.*—When a fresh-water spring in its underground course passes over a bed of rock-salt, it becomes more or less impregnated with that substance, and there results a salt spring or well. The amount of saline matter in salt springs, varies so much in character and quantity, as will be seen in the analyses given below, as to require a very decided difference in the method of treating them:—

ANALYSES OF SALT BRINES

The numbers refer to one hundred parts by weight of water.

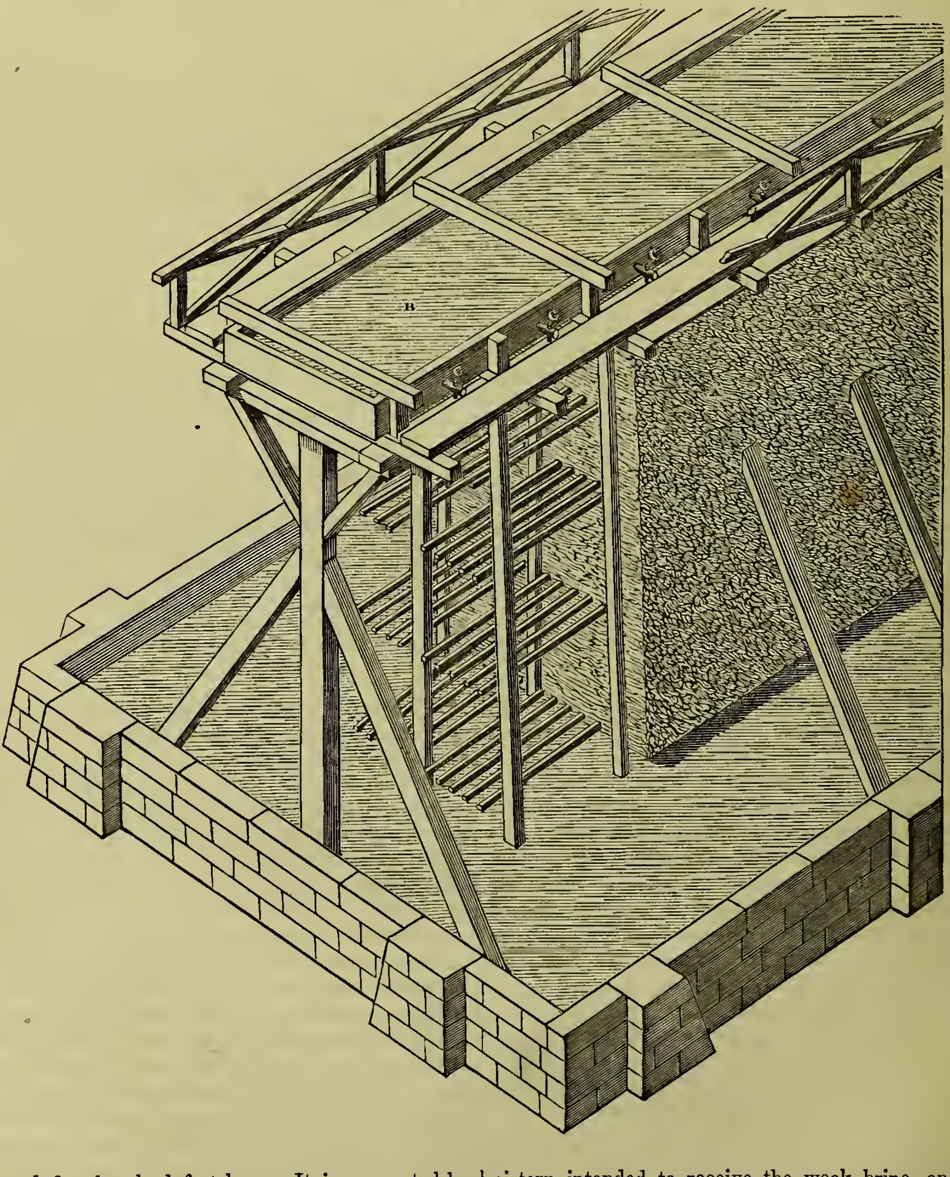
	Moutiers.	Schonebeck.	Friedrich shall.	Clemens-hall.	Hall	Sulz.	Durremburg.	Rodenberg.	Artern.	Nauheim.	Kreuznach.	Salzhansen.
Chloride of sodium,....	1·058	9·623	25·5625	25·9021	25·7180	23·4733	6·599	5·173	2·829	2·3600	1·415	0·943
" potassium,.	..	0·007	..	..	..	..	0·008	..	0·004	0·0524	0·006	0·009
" magnesium,	0·030	0·083	0·0059	..	..	..	0·092	0·166	0·038	0·0339	0·023	0·080
" calcium,....	..	..	..	..	..	..	..	..	..	0·1935	0·261	..
Sulphate of potassa,...	..	0·014	..	..	..	..	0·004	..	0·004	..	..	..
" lime,......	0·251	0·339	0·4374	0·4445	0·1705	0·5080	0·250	0·515	0·158	0·0052	..	0·080
" soda,......	0·100	0·249	..	0·0197	0·0289	..	0·208	..	0·092	..	..	..
" magnesia,..	0·055	0·012	0·0221	..	..	..	0·004	0·005	0·004	..	..	..
Carbonate of lime,....	0·076	0·026	0·0100	0·0195	0·0037	0·0162	0·026	0·010	0·042	0·2133	0·003	0·057
" magnesia,...	..	..	..	..	..	..	..	..	..	..	0·001	..
" protox. iron,	0·012	0·001	..	..	..	..	0·004	..	0·012	..	0·005	0 001
Silicic acid,...........	..	..	..	..	..	..	..	..	..	0·0021	0·013	0·001
Organic matter, ...	0·001	..	..	..	..	..	0·012	..	0·017	..	..	..
Total,........	1·593	10·354	26·0379	26·3859	25·9211	23·9975	7·207	5·869	3·190	2·8604	1·727	1·171

Salt wells are made artificially by pumping water into an excavated salt mine. The saturation of the water with salt is effected; and yet the process of pumping in pure water and drawing out strong brine made continuous by letting down a pipe into the well, opening nearly but not quite at the bottom. The water in the pipe was always much below the level of the great bulk of water in the well, because the sole opening in the pipe being near the bottom, it only allows that to ascend in it which has become dense from the quantity of salt it has taken up; and thus, while pure water or weak brine is pumped into the well, only strong brine is pumped out of it through the pipe.

When the brines are very weak, they are always made to undergo a preliminary evaporation in the air; and when the presence of sulphates and the chlorides of calcium and magnesium are calculated by their quantity to impair the commercial character of the product, certain purifying processes are had recourse to by which these are removed. When carbonate of iron is present in the weak brine, it is generally got rid of by exposing the brine for some time to the air. The carbonic acid by which the iron is held in solution gradually escapes into the atmosphere, and the carbonate of iron becomes converted into sesquioxide of iron, and falls. The muddy sediment, consisting of this and a little carbonate of lime, which also falls as the carbonic acid escapes, induces the growth of certain species of confervæ, and these impart an odor of decomposing organic matter to the water, which is, however, gradually removed in the subsequent operations. The process of evaporation with weak brines is carried on in France and Germany in what are termed graduating houses. These are large wooden structures from eight hundred to upwards of five thousand feet long by about forty feet broad, covered over at the top, and open at the sides to allow a free circulation of air through the interior. The roof covers and protects from the rain several very large but shallow wooden cisterns intended to receive the brine, or there may be only one cistern, divided by wooden partitions into several separate compartments, but the extent of these divisions, their collection under one roof, or their separation, are determined by circumstances purely local, such as the character of the water, or indeed the motive power available in distributing it. The several compartments are used to contain the brine in different stages of concentration. The first is intended to receive the brine itself; the second to receive the same after it has been concentrated by exposure to the air in minute streams, *et cetera*. The position of these graduating houses is such, that they shall be exposed in the direction of their greatest length to the prevailing winds.

Various arrangements have been devised to increase the evaporating surface of the brine; but that which now supersedes all others consists in pumping the liquor up to the summit of a high reservoir, and allowing it to trickle through the interstices of bundles of thorn built up in the form of a wall and supported by woodwork. This plan was first practised in Lombardy, thence introduced into Saxony, and in 1559 thorn stacks were used at Bavières; and the great advantages of the plan, over the thin inclined planes and long cords then employed on the continent, began to be fully appreciated and generally adopted. The particular apparatus used will be best described from the woodcut. In Fig. 510, A is the wall of thorns, usually from thirty to fifty feet high, and from one thousand two hundred to one thousand five hundred feet long. It is supported by wood beams firmly secured at the base with masonry. The thickness of the wall is nine feet at the base, diminishing to six feet at the summit; B, is a large cistern intended to receive the weak brine, and furnished with a number of small taps, C C, on either side, by which the brine may be distributed over either surface of the wall.

Fig. 510.



Weak brine is pumped up into the cistern, C, and the taps are opened on that side on which the wind prevails. The brine now slowly trickles through the thorn sticks, and from the large surface it thus exposes to the drying influence of the atmosphere the brine becomes rapidly concentrated. The brine, however, is never sufficiently strong by passing through only one stack; it is therefore pumped up again and allowed to trickle through another, and so on until the liquor has attained a particular degree of saturation, which is generally something between 22° and 32° Twaddell, depending upon the price or abundance of fuel in the locality. It is then ready to be evaporated by artificial heat.

On the thorn sticks there gradually deposits a scale, consisting of oxide of iron, carbonate of lime and magnesia, and sulphate of lime, and forming what is called *thornstone.* This incrustation at length attains such a thickness as to fill up the interstices between the sticks. The stack has then to be taken down, and the thorns renewed. This happens about every five or eight years, according to the character of the brine.

The rapidity with which water is evaporated by the use of thorn stacks is remarkable. Thus at Schönebeck the thorn surface is three hundred and ninety thousand square feet, and under very favorable circumstances evaporates 3·7 cubic feet during the twenty-four hours from each square foot. And from very careful experiments by BERTHIER, at his works at Moutiers, it appears that thirteen gallons of water are evaporated under ordinary circumstances every twenty-four hours from each square foot of thorn wall. It is a remarkable fact that the water evaporated from the thorn surface is practically proportional to the surface exposed, whatever be the density of the brine. Thus, from a series of researches made at Moutiers by the above eminent chemist, brine of specific gravity 1·010 was evaporated to 1·140, and tested at three different periods to ascertain the loss; and this, as the process of concentration advanced, is expressed by the numbers 10, 12, 11. Now, the excessive evaporation indicated during the last stage was undoubtedly due to the fact of the salt itself becoming volatilized; for the experiments of BERTHIER were conducted on a large scale, and independently of the quantity carried away bodily by the wind, one recognizes, by the sense of taste, a small quantity in the air, even when the process of evaporation is very gentle and regular. The same fact is shown in a manner more decisive in the thin incrustation of salt which may be seen on glass exposed in the vicinity of salt works; and the loss of salt from this source may be estimated at about ten per cent. The results, however, of BERTHIER's experiments show that practically the rate of evaporation between a strong and a weak brine is inappreciable; although, when the experiment is conducted with great care, so as to protect the surface of the liquid from rapid currents of air, Dr. B. G. BABINGTON has shown that the degree of concentration exerts a very decided influence in respect to the amount evaporated.

When the brine in the tanks under the thorn stacks has been brought to a specific gravity of between 1·14 and 1·16, it is run out into large settling reservoirs with just sufficient lime to decompose the chloride of magnesium. These reservoirs are of immense capacity, for the evaporation in the air taking place only during the summer months, the reservoirs are made large enough to hold a great quantity of the concentrated liquor to be evaporated during the winter months. The eight reservoirs at Salza have a capacity of nearly three million cubic feet. In these reservoirs the brine deposits all suspended matters, and the clear liquor is then run into wrought-iron tanks to be evaporated to dryness. The process of evaporating the brine to the point of saturation is termed the *schlottage* of the salt. The further evaporation to obtain dry salt is termed the *soccage.*

SCHLOTTAGE.—The pans used in this operation are from about sixty to eighty feet long, by from twenty to forty feet broad, and two feet deep, and are made of thin sheets of wrought-iron rivetted together. Each pan is heated by two or even four fires, and the flues are so built that the heat shall be distributed over the whole bottom of the pan in a manner as effective as the brick supports for the pan will allow.

The pans being three parts filled with brine, and a little blood or grease added, are brought as rapidly as possible to the boiling point. A scum now forms on the surface, which is skimmed off. This scum consists of the organic matter in the brine, and a little bitumen, which is found in all brines from natural springs. In the meanwhile the brine, which is saturated with sulphate of lime, gradually deposits this on the bottom of the pan. When about one-fourth of the original brine has been evaporated, new brine of specific gravity 1·16 is again pumped in, and the process of boiling and removing the scum is continued until the brine in the pan has been brought almost to the point of saturation; it is then run into other pans of a similar shape, and about equal capacity, to be evaporated to dryness.

The deposit on the bottom of the schlotting-pan gradually attains a thickness calculated to interfere very materially with the conducting power of the iron, and so occasions much loss of heat; the pan has then to be scaled. Of course the necessity for performing this operation will vary considerably with the degree of purity of the salt. It is usual, however, to scale the pan after it has been filled up from eight to about fifteen times.

The deposit consists of sulphate of lime and sulphate of soda, inclosing mechanically a quantity of common salt.

SOCCAGE.—This operation is performed in wrought-iron pans, similar to those described before for the schlotting process. They inclose an area of about four hundred square feet. The bottom of the pan inclines a little towards the centre. Over the pan is a dome-shaped structure of wood, terminating in a kind of chimney, for the purpose of carrying away the vapor. The woodwork supporting the dome is open at the side, immediately over the pan, that there may be a free circulation of air over the surface of the brine. During the beginning of the boiling down the pans are briskly heated; towards the end, when much salt becomes deposited on the bottom, the fires are slackened, that the bottom of the pan may not be burned.

The process is continuous, the salt being taken out as it falls by means of scoops, perforated at the bottom, to allow the mother-liquor to percolate.

In the case of lime having been added in the settling pan, or at the beginning of the schlotting process, the mother-liquors do not become too impure to be evaporated down to dryness, even after the pan has been filled up with new brine several times. There is also an additional advantage experienced at this stage of the manufacture, from lime having been added to throw down magnesia, inasmuch as, during the process of evaporation, chloride of magnesium forms a crust on the surface of the liquid, which re-forms almost as soon as broken, thereby preventing very materially the escape of vapor. The formation of the crust, however, may be avoided equally well by the addition of a little sulphate of soda. An interchange of elements is thus occasioned; the sulphuric acid of the soda going to the magnesia to form sulphate of magnesia, and the chlorine of the magnesium passing to the soda to form chloride of sodium. The soccage pan requires chipping out about once a month or rather oftener.

Salt having been removed from the crystallizing pans by the strainers, is collected into larger heaps on a perforated floor to drain further; it is then transferred to the drying chamber. This is simply a long chamber, heated by the flues from the fires used to evaporate the brine. These flues converge into one or two main flues, which are made to pass along the bottom of this chamber. The salt is either packed up in shallow wicker baskets, or it is put into moulds, and these are piled up above the flue in the drying chamber, and there allowed to remain until the salt no longer loses much moisture, when it is fit for the market.

In England, all the salt prepared is obtained from the evaporation of strong brines by artificial heat. The brines used are saturated, or nearly saturated solutions of salt in water, containing from 23 to 26·5 per cent. of pure chloride of sodium, besides other constituents; while a saturated solution of salt in water only contains 27 per cent. of salt. Indeed, several experiments tend to show that some brine springs would seem to hold in solution more chloride than would be taken up by the same amount of water, however long it were left in contact with dry salt.

The brine springs of Cheshire do not rise to the surface of the ground. They emerge from the surface of the rock; and when the spring is tapped, will rise in the bore hole from eighty to ninety feet. In the neighborhood of Winsford and Northwich, a shaft is sunk in the ground six feet square, and about one hundred and eighty feet deep. The sides of the shaft are carefully boarded with planks, and an inner planking of six inch boards, four feet square, is then built in, and the space between the boards well puddled with clay, to keep out the fresh-water surface springs. The inner boarding is firmly built in, and made more secure by cross-stays of stout wood. An iron pipe about nine inches internal diameter is then let down into the boring. The brine will rise in this pipe about ninety feet; it has consequently to be lifted by a pump to about the same extent. A continuation of the pipe from the pump conducts the brine into a larger reservoir lined with masonry. This reservoir, which may be about two hundred feet long by about sixty or eighty broad, and perhaps six feet deep, is not built for the purpose of allowing sedimentary matter to deposit, for the brine as it is pumped up is perfectly clear and free from particles in suspension. It is of a clear sea-green color, and the reservoirs are built to serve merely as a store of brine on a high level, and from which it may be drawn down to supply the evaporating pans as needed.

The evaporating pans are contained in a shed which may be four hundred feet long by about eighty feet broad, and about thirty feet high, open at the sides to permit a free current of air to pass over their surface. The pans are set in a firm foundation of brickwork, which does not, however, extend up the sides. There are generally four furnaces to each pan, and the flues, so built as to support the pan, radiate over the whole of the bottom. There are usually three pans in a series, under two of which furthest removed from each other are the fire-places. The flues passing under these are continued under the third, and meet in the centre, at which point they unite into one, and the flue is connected with the chimney; but so as to economize as much as possible the heat of the flue, a chamber is built over it in its course to the chimney, and this is made use of as a drying stove for the squares of salt.

The Cheshire brines, which are of specific gravity 1·200, and contain about 24 per cent. of common salt, are of so pure a quality that they require no preliminary februation. The brine is, therefore, at once run into the evaporating pans, which are of sizes varying with the source of heat, and evaporated by the direct action of the fire, or by the waste heat of the steam engine used to pump up the brine.

Those pans in which the salt is evaporated by a boiling heat, are about twenty feet square and eighteen inches deep. Those where a lower temperature is used, are about forty feet long by twenty broad, and two feet deep. The pans are made of quarter-inch iron boiler-plates rivetted together. They incline somewhat towards the end furthest removed from the fires, that more salt may be deposited on that part. The inclination is from six to eight inches in the whole length.

Three kinds of salt are manufactured in Cheshire; the difference, however, consists in the size of the crystal, depending upon the rapidity with which the evaporation is conducted. Thus the finest-grained salt is made by rapid boiling; the coarsest at a temperature of about 150°; and the medium quality between these two points.

The evaporating processes are conducted as follows: —Brine is run into a pan until it is three parts full; a little glue, and sometimes a little waste grease is then thrown in to assist in the formation of a scum, and partly to prevent the crystals of salt as they fall from adhering to the bottom of the pan. The brine is then brought to the boil as rapidly as possible, and a scum which forms on the top is removed by lightly skimming the surface with a piece of board. The crystals of salt begin to separate almost as soon as the brine is brought to the seething point, and when about half the water has been evaporated fresh brine is run in. The salt that has boiled out is removed twice in the twenty-four hours. This operation is effected by a perforated scoop, and the salt is put into wooden moulds, or tubs, about eighteen inches high and nine inches broad at the top, and diminishing to about seven inches at the bottom. These tubs are put into the salt pan to be filled, and stand on a ledge on the side about six inches from the bottom of the pan. When the tubs are filled the salt is slightly pressed down, and the tubs are removed from the ledge on to a perforated floor, so that the mother-liquor may drain away from the salt. To allow of this there are two slits in the bottom of the tub. When the salt in the tubs has drained twelve hours, the tubs are reversed, and then withdrawn from the squares of salt, which are removed to the drying chamber, where they are allowed to remain until they become dry. From a salt-pan twenty feet square two hundred tubs of salt, each containing thirty pounds of dry salt, are removed in a day. The pans are not allowed to cool, except for purposes of cleansing, the brine being repeatedly pumped in, and the process of evaporation being continuous. About once a week the salt is more thoroughly removed than usual, and the brine in the pan allowed to run low; the pan is then seated over the fireplace. This operation, called *dodging* or *scabbing*, is performed with a pickaxe furnished with a long handle, and having the iron flukes flattened at the ends. A man stands on the floor that runs round the pan, and by striking with the axe he loosens the incrustation, and then removes it with a rake and spade. The scab consists of a little clay and sulphate of lime, but principally of common salt which has been burnt on to the bottom of the pan. When a pan has been worked for a month, a scale will have gradually formed over the entire bottom. The whole of the salt is then removed, the fires put out, and the mother-liquors, being of little value where there is such abundance of brine, are run away. The whole underpart of the pan is then scaled with a hammer and chisel.

The brines of Worcestershire are of higher specific gravity than those of Cheshire, and contain twenty-six per cent. of salt; but the method of working does not differ in any essential particular from the description given, and, therefore, they do not require a separate notice.

The following tables, by Dr. CAMPBELL MORFIT of New York, show the constitution in one gramme of various samples of salt:—

RANK.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Commercial Brand, and Source of the Specimen.	Key, West Solar, Florida.	St. Martin's	Liverpool Rock.	Kiskiminitas from Tarentum, Pa.	Oso	Liverpool fine.	Liverpool ground alum.	Cudwell's boiled, from Syracuse, New York.	New York.
Chloride of sodium, ...	0·993514	0·985266	0·982713	0·977931	0·975485	0·969917	0·969423	0·968882	0·968488
Water, ...	0·008000	0·007000	0·005000	0·019000	0·020000	0·005000	0·014000	0·012000	0·012000
Insoluble residue, ...	0·000050	0·002000	0·006000	0·000200	0·000300	0·000400	0·000700	0·000400	0·001100
Chloride of potassium, ...	....	....	....	....	....	....	....	....	....
Chloride of calcium, ...	0·000119	....	....	0·003017	....	....	....	....	0·002671
Chloride of magnesium, ...	0·000934	0·002123	0·002547	0·000849	0·002123	0·006708	0·005774	0·000849	0·002547
Sulphate of lime, ...	0·000554	0·000510	0·001700	....	0·001900	0·010005	0·003011	0·014300	0·015624
Sulphate of potassa, ...	....	....	S. trace.	....	....	trace.	S. trace.	....	trace.
Sulphate of soda, ...	....	0·002520	0·000659	....	0·001364	0·004330	0·007628	0·003085	....
Nitrate of soda, ...	trace.	....	S. trace.	trace.	....	....	....	....	trace.
Silicate of soda, ...	trace.	0·000336	0·000505	0·000252	0·000505	....	trace.	trace.	....
Organic matter—soluble, ..	....	....	....	....	trace.	....	....	....	....
Iron (Fe_2O_3), ...	0·000800	0·000400	0·001100	0·000200	trace.	0·000500	0·000700	0·000400	0·000800
Alumina (Al_2O_3), ...	....	0·000200	....	0·000500	0·002000	0·000600	0·000900	0·001200	0·000500
Total, ...	1·003971	1·000355	1·000224	1·001949	1·003677	0·997460	0·999136	1·001116	1·003730

RANK.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
Commercial Brand, and Source of the Specimen.	Kanawha, Virginia.	Haskin's salina, coarse, from Syracuse, New York.	Goose Creek, Kentucky.	Bonaier,	Spencer's boiled, from Syracuse, New York,	Hope Factory, New York.	Nassau.	Anguila,	Syracuse Company, New York.
Chloride of sodium, ...	0·967460	0·965540	0·964276	0·963288	0·962938	0·962851	0·960321	0·957348	0·956663
Water, ...	0·022000	0·014000	0·022000	0·017000	0·022000	0·014000	0·011000	0·022000	0·016000
Insoluble residue, ...	0·000600	0·000000	0·000300	0·001000	0·000300	0·000600	0·001000	0·005800	0·001800
Chloride of potassium, ...	S. trace.	....	S. trace.	....	trace.	....	....	....	....
Chloride of calcium, ...	0·003257	....	0·007747	....	0·000009	....	....	....	....
Chloride of magnesium, ...	0·002887	0·000509	0·001613	0·007132	0·002717	0·002123	0·008665	0·002293	0·000509
Sulphate of lime, ...	....	0·014500	....	0·004000	0·013992	0·016500	0·004800	0·008600	0 020000
Sulphate of potassa, ...	....	S. trace.	....	S. trace.	....	trace.	trace.	....	....
Sulphate of soda, ...	....	0·000809	....	0·006777	trace.	0·000667	0·009562	0·004410	0·002978
Nitrate of soda, ...	trace.	....	....	....	....	....	trace.	trace.	....
Silicate of soda, ...	0·000421	0·000252	trace.	0·000168	0·000168	0·000168	0·000673	0·000168	0·000168
Organic matter—soluble, ..	....	trace.	....	....	trace.	....	....	....	....
Iron (Fe_2O_3), ...	0·000400	0·000500	....	0·000500	0·800800	0·000600	0·000500	0·000200	0·000700
Alumina (Al_2O_3), ...	0·000400	0·001300	....	0·001700	0·001700	0·002000	0·000500	0·001200	0·001300
Total, ...	0·997325	0·998010	0·995936	1·001565	1·004624	0·999509	0·997021	1·002019	1·000118

TABLE—(*Continued.*)

Rank.	XIX.	XX.	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.
Commercial Brand, and Source of the Specimen.	Tarentum, Pa.	Liverpool Ashton.	Turk's Island.	Pomeroy, Ohio.	Curaçoa.	Alleghany saline, Penna.	Cadiz.	St. Ubes.	Inagua.
Chloride of sodium, ...	0·943494	0·941656	0·940776	0·938382	0·929816	0·915437	0·913722	0·890402	0·878509
Water, ...	0·040000	0·044000	0·032000	0·046000	0·053000	0·064000	0·063000	0·061000	0·096000
Insoluble residue, ...	0·000300	0·000500	0·003600	trace.	0·001500	0·000800	0·001700	0·001900	0·005000
Chloride of potassium, ...	....	....	....	S. trace.	....	....	....	....	....
Chloride of calcium, ...	0·007541	....	....	0·008971	....	0·013495	....	....	0·004844
Chloride of magnesium, ...	0·008491	0·002462	0·007047	0·005095	0·011036	0·005394	0·010699	0·023870	0·000594
Sulphate of lime, ...	0·002740	0·012200	0·009400	....	0·002300	....	0·003300	0·009800	0·013059
Sulphate of potassa, ...	....	trace.	trace.	....	trace.	....	trace.	trace.	....
Sulphate of soda, ...	....	0·001262	9·007530	....	0·007208	....	0·009942	0·014475	....
Nitrate of soda, ...	trace.	....	....	....	....	....	trace.	....	trace.
Silicate of soda, ...	0·000336	0·000421	....	trace.	trace.	0·000505	0·000252	0·000337	0·000336
Organic matter—soluble, ..	....	....	....	....	....	....	....	....	....
Iron ($Fe_2 O_3$), ...	0·000200	0·000200	0·001000	trace.	trace.	0·000200	0·000300	0·000400	0·000100
Alumina ($Al_2 O_3$), ...	0·000600	0·000200	0·000600	trace.	trace.	0·000200	0·000700	0·000500	0·000200
Total, ...	1·003702	1·002901	1·001953	0·998448	1·004860	1·000031	1·003615	0·002682	0·998642

This article would be incomplete without adverting to the saline springs of Syracuse, in the state of New York. Numbers VIII., XI., XIV., and XVIII., in the analyses by Morfit are samples from this district. The springs of Syracuse, to which in a great measure the growth and prosperity of New York are attributable, are among the most interesting natural productions with which America is blessed. They occupy a circuit of about nine miles around the Southern extremity of the Onondaga lake. The salt is obtained from the water by the heat of the sun. The process of obtaining salt by solar evaporation is very simple. A series of wooden vats are built, twelve feet wide, six inches deep, and several rods in length. The brine is let into the first tier direct from the reservoir, and is left in repose until the dirt and other impurities have subsided. The clear supernatant liquor is then drawn off by siphons into the second tier of vats, which are lower than the first, where the sulphate of lime is deposited in beautiful crystals. The brine, thus purified, is redrawn off into the third and lowest tier of vats, where by exposure it evaporates, and the crystallization of chloride of sodium commences. At first the crystals are seen on the surface of the brine, and resemble drops of melted tallow let fall upon a surface of cold water. These particles accumulate, and precipitate themselves to the bottom of the vat in large quadrangular and hexangular crystals of the purest salt, hard, dry, and of a beautiful white color. This Onondaga *solar* or coarse salt is unsurpassed, it is said, in the world, and its antiseptic properties are widely known and appreciated. The rapidity of the process, and the consequent proportional crop, depends upon the heat of the weather; the process of evaporation being greatly retarded by a humid atmosphere. Sunshine is of course desirable at the salt works, and the superintendent keeps a close watch upon the weather. At the first symptoms of a shower all hands are immediately summoned to *push on the covers*, and the temporary roof, which is passed on rollers over the crystallizing brine, is ready to be removed the very instant the sun shines again.

The state of New York, through its superintendent, bores the wells, procures the supply of brine, and conducts it through logs to the salt works, which are the property of individuals. The localities are leased at a nominal rent, and for an indefinite number of years, but are only to be employed for the manufacture of salt. For the *raw material* a tax of one cent per bushel is levied on every bushel of salt produced. This amounted in 1856 to fifty-nine thousand nine hundred and forty-six dollars and forty-four cents; the expenses were fifty thousand two hundred and fifty-five dollars and sixty-five cents.

Physiological Effects.—In minute quantity chloride of sodium is injurious to very few, if any plants, and to some it appears to be beneficial. Used moderately, it is on certain lands a most excellent fertilizer.

Salt serves many important and essential uses in the animal economy. It is employed, on account of its agreeable taste, by the people of all nations. It is an invariable constituent of the healthy blood. There is a deficiency of this saline constituent in cholera.

As a chemical antidote, chloride of sodium may be administered in poisoning by nitrate of silver. As an alterative and tonic, it is useful in scrofula and glandular diseases. As an astringent in hemorrhage. dysentery, and diarrhœa, it has been given in conjunction with lime or lemon juice. It is frequently employed as a dentifrice.

As an external application, salt has been employed for various purposes. A saturated solution, applied with friction, is used as a counterirritant and discutient in glandular enlargements and chronic diseases of the joints; as a stimulant, it is rubbed on the chest in fainting and asphyxia.

The inmates of every sea-side infirmary can tell a yet happy tale of the beneficence of salt breezes. They speak of lingering diseases fortunately ended; of long convalescence speedily consummated by cure. Many a life which seemed gradually ebbing away in the atmosphere of a crowded city hospital, have these briny vapors called back and fortified, and cheered with long years of health. Salt plays here the part of a good fairy: it makes of this infirmary a kind of healing heaven for the bodily sick.

The duty on salt was repealed in 1823; but in 1815 the makers of bleaching powder were allowed to use rock salt duty free, under the inspection of the excise, who required that the salt should be crushed at the mines and mixed with a certain proportion of ground manganese, so as to render it unfit for curing purposes. The Editor's father decomposed salt which was six pounds a ton in Dublin in the year 1819. Mr. MUSPRATT mixed it with oil of vitriol, condensing the evolved hydrochloric acid in a series of stone jars. It was in Liverpool, in 1823, that he first decomposed salt in an *open* furnace, *disregarding entirely the hydrochloric acid*, which escaped and was diffused throughout the atmosphere. The salt he employed at first was termed *herring salt*, and cost forty shillings a ton. The price now is only eight shillings.

RETURN OF SALT COMPILED AND ISSUED BY THE NORTHWICH AND WINSFORD CHAMBER OF COMMERCE.

	Tons.
White salt carried on the river Weaver from 5th April, 1857, to 5th April, 1858,	647,437
Rock salt,	65,773
Carried by rail from Winsford and Northwich, estimated at	525,000
WORCESTERSHIRE.	
Stoke and Droitwich,	196,500
IRELAND.	
Duncone, near Carrickfergus, belonging to the Belfast Mining Company, shipped	16,660
Used for manufacturing purposes,	5,798
White salt manufactured,	4,877
Total produce of the United Kingdom,	1,462,045

TOTAL QUANTITY OF WHITE SALT EXPORTED FROM JANUARY 1 TO DECEMBER 31.

	Tons.
1855,	583,770
1856,	720,689
1857,	648,516
ROCK SALT EXPORTED.	
1857,	87,119

SULPHATE OF SODA.—GLAUBER'S SALT.—SALT CAKE.—*Sulfate de Soude*, French; *Schwefelsaures, Natron*, German.—This salt was discovered by GLAUBER in 1658, and since that time has been commonly known by his name. It exists in nature in both the mineral, vegetal, and animal kingdoms. It is a very common ingredient of mineral springs of the purgative class, and is also one of the salts met with in small quantity in most terrestrial waters. Amongst the English medicinal waters, it exists in considerable quantity in those of Cheltenham, of Leamington, and of Spital. In some springs, as in that of Paipa among the Andes, it is so abundant that crystals of it are formed upon the surface over which the water is thrown; it is likewise found in crystals in the brine springs at Salinas d'Espartinas, near Madrid. In the latter locality the sulphate exists as *Thenardite;* while in the former it is in the hydrated state, or *Mirabilite.* GMELIN accounts for its presence in mineral waters, on the supposition that it is formed by double decomposition from common salt and sulphate of magnesia contained in the liquid, thus—

$$\underbrace{Na\,Cl}_{\text{Chloride of sodium.}} + \underbrace{Mg\,O\,SO_3}_{\text{Sulphate of magnesia.}} = \underbrace{Na\,O\,SO_3}_{\text{Sulphate of soda.}} + \underbrace{Mg\,Cl}_{\text{Chloride of magnesium.}}$$

Sulphate of soda in the form of mirabilite is also found in several localities in Austria, in Bohemia, in the Tyrol, and in several places in Spain and Hungary, as well as in Switzerland; on lavas, and as an efflorescence on the Siberian and Caspian steppes. A mixture of the crystallized salt with gypsum—*Glauberite*—was discovered by GIMBERNAT in the canton of Argovie in Switzerland; the same compound has been found in crystals and reniform masses, embedded in rock salt, at Villarubia in Spain, at Vic in Lorraine, Berchtolsgaden in Bavaria, and at Atacama in Chili. In the vegetal kingdom, sulphate of soda is found in the ashes of some plants which grow by the sea-shore, as the *Tamarix gallica;* and lastly, it is found in some of the animal fluids, as the blood and urine. Artificially this salt is extensively made, and its production being the first stage of the process for the conversion of common salt into carbonate of soda, it is a most important article in commerce.

It is obtained by heating common salt with sulphuric acid, and is also a by-product in the preparation of nitric acid, of sal ammoniac, of carbonate of magnesia, in the amalgamation of silver ores; and it may also be obtained from many glass slags, if native or artificial soda has been used in the preparation of the glass.

Preparation.—Sulphate of soda may be most conveniently prepared in the pure state, by causing liquid sulphuric acid to react on chloride of sodium. When the two substances are mixed, violent effervescence ensues, hydrochloric acid being evolved; the effervescence having partially subsided, heat is applied to the vessel, and continued until the whole of the hydrochloric acid is expelled, and the mass becomes dry. The following diagram shows the change that takes place:—

$$58{\cdot}5 = 1\text{ Eq. chloride of sodium,}\ldots\ldots\left\{\begin{array}{l} 35{\cdot}5 = 1\text{ Eq. chlorine,} \qquad 36{\cdot}5 = 1\text{ Eq. hydrochloric acid.}\\ 23 \;\;= 1\text{ Eq. sodium,}\end{array}\right.$$

$$49{\cdot} \;= 1\text{ Eq. hydrate of sulphuric acid,}\left\{\begin{array}{l} 1 \;\;= 1\text{ Eq. hydrogen,}\\ 8 \;\;= 1\text{ Eq. oxygen,}\\ 40 = 1\text{ Eq. sulphuric acid } 71 = 1\text{ Eq. sulphate of soda.}\end{array}\right.$$

The dry mass obtained as above, usually contains a little sulphuric acid more than is required to produce neutral sulphate of soda. This is removed, after solution in water, by the addition of a sufficient quantity of carbonate of lime, or the excess of acid may be neutralized by the addition of carbonate of soda. The solution is now to be filtered, evaporated, and set aside to crystallize. The crystals obtained by resolution and recrystallization yield the salt chemically pure. Or the menstruum may be obtained directly by dissolving carbonate of soda in dilute sulphuric acid.

Crystallized sulphate of soda, procured as above, contains to each equivalent of sulphate ten equivalents of water, and consequently, is represented by the formula $Na\ O, SO_3, 10\ HO$. The anhydrous salt is obtained by heating the crystals to redness, or, according to **FARADAY**, in anhydrous crystals, by evaporating an aqueous solution at a temperature considerably below 212°. **MISTCHERLICH** gives the degree at 104°, and others state it to be as low as 91°.

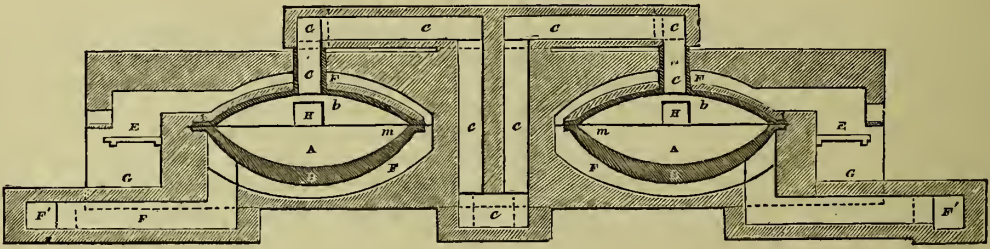
Properties.—The primitive form of the ordinary crystallized sulphate is the oblique rhombic prism. The anhydrous salt forms in crystals belonging to the right prismatic system. This latter, which is transparent, when exposed to the air becomes opaque on the surface, owing to absorption of water. The taste of the crystallized salt is cooling and bitterish saline. By exposure to the air it effloresces, with the loss of all its water. The perfectly effloresced salt intumesces in very moist air to three times its bulk, and then becomes a crystalline mass of ordinary Glauber's salt, with a slight excess of water. When the crystallized salt is heated, it undergoes the aqueous fusion, gives off its water, and thereby becomes a white solid; but at a red heat this again becomes liquid. One part of the crystals dissolves in three parts of water at 60°; at 212° water dissolves its own weight of the salt. It is insoluble in alcohol. A crystallized sulphate of soda is also known, containing eight equivalents of water, and having the formula $Na\ O\ SO_3, 8\ HO$.

Physiological Effects.—Sulphate of soda is a mild but efficient cooling laxative or purgative salt, promoting secretion and exhalation from the mucous membrane of the stomach and bowels without causing inflammation or fever. It was formerly the most favorite saline cathartic in this and other European countries, but since the beginning of the present century has gradually been displaced by the sulphate of magnesia.

Manufacture of Sulphate of Soda.—Sulphate of soda possesses more than a chemical interest. Its preparation, as previously mentioned, is the first stage of the process now so extensively carried on for the conversion of common salt into carbonate of soda. In the production of the dry salt, technically known as *salt cake*, sulphuric acid is caused to act upon common salt in a proper apparatus, the products of the reaction being salt cake and hydrochloric acid. Until of late years the decomposition was effected in an ordinary reverberatory furnace, named the decomposing furnace. Some furnaces of this kind were constructed with two compartments, in one of which the materials were mixed, the greater part of the gas liberated, and the liquid evaporated to a pasty condition; in the other the calcination of the residuary sulphate was effected. In many decomposing furnaces the whole operation was carried on in the same division. An important improvement on this plan of decomposition was effected by introducing into the decomposing bed of the double furnace a lining of sheet lead, upon which the materials are mixed and brought to a pasty consistence, and they are then removed to the roasting bed to be more completely freed from acid. Furnaces of this kind are still in use in many alkali works. But for the most complete apparatus for the production of salt cake, manufacturers are indebted to Mr. JOHN LEE, who proposed the substitution of a concave iron pan for the leaden one previously employed. The advantages obtained by the use of these pans are, first, a great diminution of the expense of production, since the leaden pans rapidly become corroded during the process; and, secondly, that with the iron pan a much stronger sulphuric acid may be employed to effect the decomposition, with the further advantage of preventing the formation of so much bisulphate of soda as by the old method.

A description of the annexed woodcuts—Figs. 511 to 514—will show the most approved form of apparatus in use at the present day. Fig. 511 is a transverse section of two decomposing pans, A, A, formed of cast-iron, weighing about five tons each, and suitably set in brickwork, so as to allow the bottom and sides to be exposed to the fire. The pans are covered with a sheet of iron, *b*, the joints made good with luting. E is the fireplace; and the flues, F, F, pass over and under the pans, but not through them. The roof of the pan is not always constructed of iron; a brick roof is frequently in use, the arch being higher in proportion to allow of its being self-supporting.

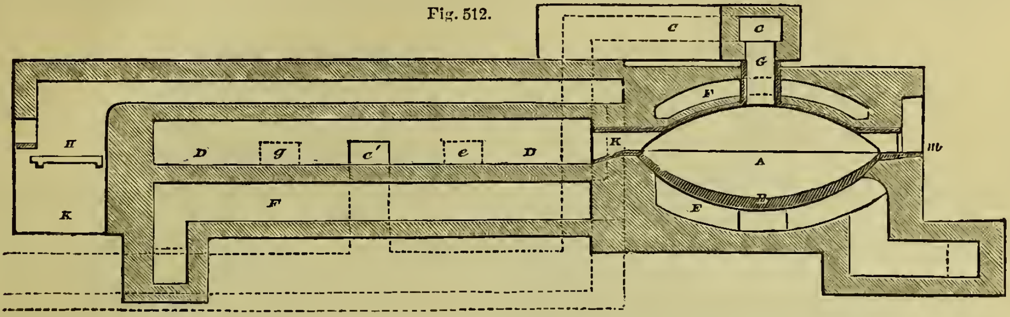
Fig. 511.



There are three openings into each of the pans, one through which the charge is introduced, and shown at H; the other immediately opposite, through which the charge is pushed out, seen at K, in Fig. 512; the third is for the escape of the acid vapors through the pipe, C C. This pipe is composed of short lengths of closed earthenware fitting into one another, and well luted to prevent escape of gas.

Two of these pans are usually worked together, and the hydrochloric acid gas brought into one main flue, as shown in the figure. The salt cake furnace is attached to the decomposing pan, as shown in Fig. 512. The sole of this furnace, which is flat, is constructed of good fire-brick or Welsh tiles, and the roof, which is only slightly arched, is of fire-brick. H is the fireplace, and F F are the flues passing over and under the furnace, but not through it. G and E are openings for the purpose of turning over and withdrawing the charge. C is the tube through which the acid gas escapes.

Fig. 512.



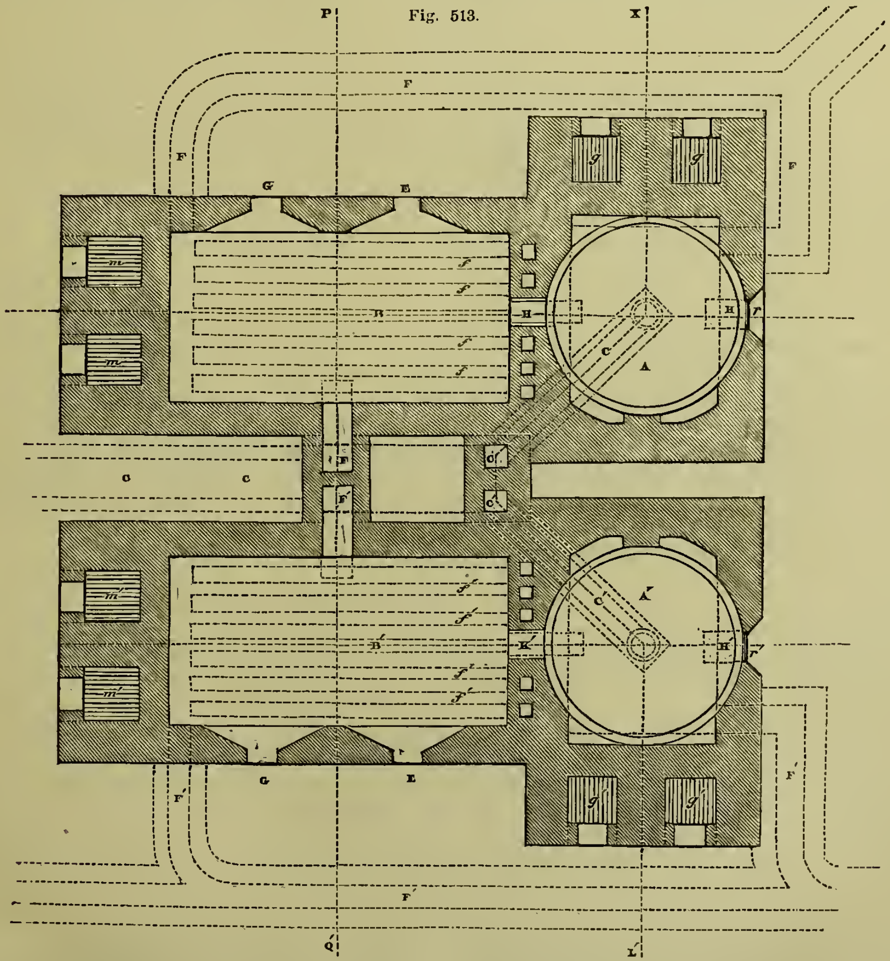
The charge is pushed into the furnace from the decomposing pan through K.

Fig. 513 shows a plan of the decomposing pans and furnaces. A A′ are the decomposing pans; C C′, the acid flues; F F′, and the dotted lines, *f f f*, show the arrangement of smoke flues.

Fig. 514 is a transverse section of the same through P, F, Q, in which the arrangement of flues is plainly seen.

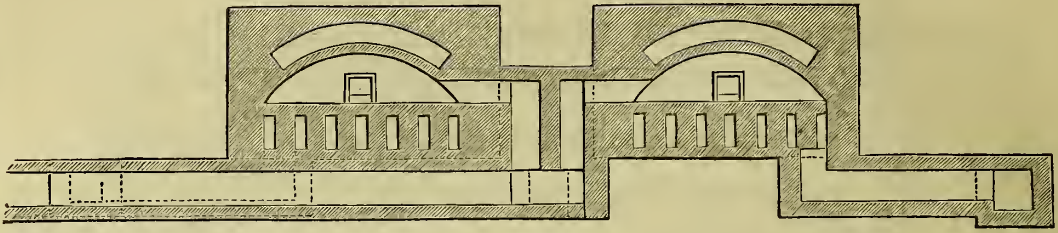
The following is the method of producing salt cake with the use of the apparatus described. The pan, A, is first heated to a suitable temperature, and the charge of salt, amounting to about sixteen hundredweight, is introduced through the doorway, H. The tile which closes this is now fitted into its place, and the sulphuric acid is run in. It is preferred to use acid of about specific gravity, 1·450, and heated to a temperature of about 120°, so as not to cool the pan more than is neces-

Fig. 513.



sary. The proportion of acid required is about one thousand eight hundred pounds, or one hundred and twenty-three and a half gallons, that being the quantity which, making allowance for water and slight impurities in the salt, is just sufficient to convert all the chloride of sodium into sulphate of soda; and the charge is usually measured out by filling a small leaden vessel, of known capacity, placed near or over the decomposing pan, so as to allow of the acid being run in upon the salt by a siphon. The acid and salt having both been introduced, the tile closing the opening, H, is now removed, and the materials thoroughly mixed with an iron rake. This mixing serves at the same time to prevent frothing, by facilitating the escape of gas. The doorway is then effectually closed with the tile and proper luting, and the fire urged under the pan. In the course of an hour nearly all the acid vapor will have been disengaged, and the greater portion of the common salt be converted into sulphate of soda. Much of the sulphuric acid, however, is now found combined with soda as bisulphate of soda; and to decompose this, so as to render the excess of acid serviceable in forming sulphate of soda with the undecomposed common salt, a high temperature is required, to obtain which the charge is now pushed forward through the opening, K, into the salt cake furnace, D D′—Fig. 512—by means of rakes inserted through H. The charge is spread evenly over the floor of the furnace, the tools being worked through the doorways, E and G. The salts are here exposed to a low red heat for about one hour, and frequently turned over during this interval. Meanwhile the decomposing pan having remained empty for a time, to enable the workman to raise the temperature to the proper extent, a new charge of common salt and acid is introduced, and worked off in the manner described.

Fig. 514.



The sulphate of soda is heated in the salt cake furnace until it assumes a reddish-yellow tint, when it is raked out through the doorway, G, and is considered finished.

From two furnaces, such as shown in the drawings, and of the dimensions given, ten charges each may be drawn in a day, or sixteen tons of common salt may be decomposed, with the production of nearly nineteen tons of salt cake. The working of sulphate of soda is effected, however, under different arrangements, in a manner even more rapid than this. Thus, when an open reverberatory furnace is used in place of the closed furnace described, sixteen charges a day may be drawn; the open furnace being capable of more rapid heating than the *blind or closed furnace* described, and the acid gases being more readily carried away by the current of air passing over the heated salt.

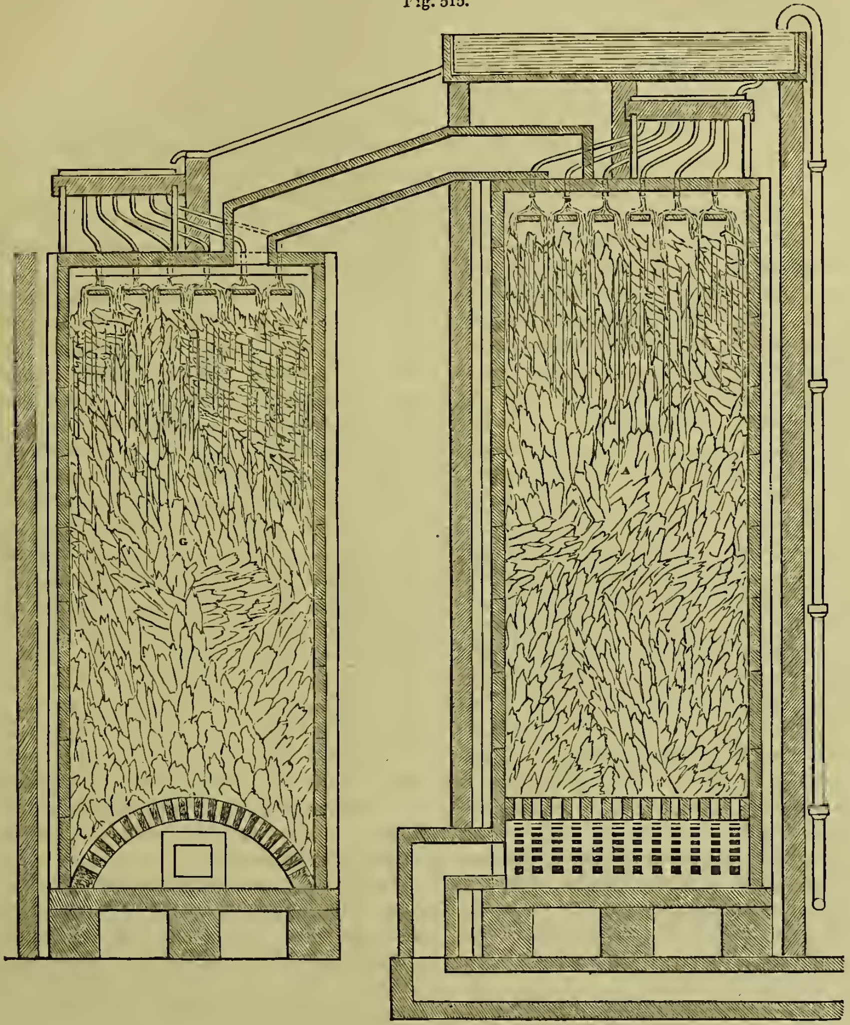
Condensation of the Hydrochloric Acid.—It now remains to consider the various plans adopted to effect the condensation of the hydrochloric acid gas evolved from the mixture of acid and salt. The whole or nearly the whole of this was, in the early days of the manufacture, allowed to escape into the air, the inconvenience attending its condensation having been considered of greater consequence than the value of the liquid acid. But owing to the great demand for bleaching powder, the manufacturer found it would be to his interest to condense *the whole* of the acid, so as to use it in the preparation of bleaching agents.

The plan of apparatus at present employed for effecting the condensation of gaseous hydrochloric acid to the liquid form, was first suggested and patented in 1836 by Mr. GOSSAGE; the condensers have, however, been greatly improved since that period. The gas, as evolved from the mixture of sulphuric acid and salt, is conducted by means of pipes inserted in the brickwork of the dome of the pot, and in the arch of the furnace, to a massive tower or series of towers—Fig. 515—constructed of large rectangular slabs of silicious stone, cemented together and bound exteriorly by stout iron clamps. These towers may be filled with small pebbles or rounded flints, but usually coke is preferred, and a stream of water is allowed to flow from a cisternon the top slowly through the mass; this, meeting with the ascending gas, completely condenses it, and ultimately flows out by an aperture in the bottom to a recipient. The mode of condensing adopted previously to the introduction of these towers was, as previously stated, by a series of WOULFE'S bottles; a system far too cumbrous to be adopted successfully on the very extensive scale on which the manufacture is now carried on.

A connection exists between the first and second towers near the summit, and from the base of the second tower an underground flue, for the purpose of creating a draught through the apparatus, is carried to the chimney-stalk. The gases eliminated from the mixture of salt and sulphuric acid enter the first tower at its base, and pass upwards through the moistened coke; whatever is uncondensed is carried into the second tower, and in its passage through this downwards the whole of the acid is removed; and the uncondensable gases pass by the flue to the chimney.

If the towers are of sufficient height, two only will be requisite to effect complete condensation of the acid; but if this should not be the case, three or more may be connected together; the first two at the summit, the second and third at the base; the third with the fourth at the top, and so on through the series. By this arrangement acid may be obtained of specific gravity 1·150 to 1·160, quite strong enough for the decomposition of binoxide of manganese.

Fig. 515.



If the hydrochloric acid be required for other purposes than the decomposition of binoxide of manganese, as for the evolution of carbonic acid from chalk or limestone, condensers of a still more simple nature may be employed; because then, a weaker acid answering the purpose equally well with a strong one, a far greater proportion of water may be used. In this case, a single tower divided into two compartments by a partition wall, and the whole well filled with small pieces of coke and supplied with water in sufficient quantity, will effect the condensation of the whole of the acid evolved. But unless the acid can be at once consumed on the spot, it is of course always desirable to obtain it in as concentrated a condition as possible. In some manufactories, as well to prevent the escape of hydrochloric acid as for economy, the towers, constructed as above described, are filled with limestone instead of coke or pebbles; and the carbonic acid evolved is applied in the preparation of bicarbonate of soda, as will be hereafter mentioned. It has also been proposed to avoid the evolution of hydrochloric acid altogether, by adding sulphuric acid and zinc to a solution of chloride of sodium. In this case, hydrogen is eliminated, and there is produced chloride of zinc and sulphate of soda as in the annexed equation:—

$$\underbrace{\mathrm{Na\,Cl}}_{\text{Chloride of sodium.}} + \underbrace{\mathrm{Zn}}_{\text{Zinc.}} + \underbrace{\mathrm{SO_3\,HO}}_{\text{Sulphuric acid.}} = \underbrace{\mathrm{Na\,O,\,SO_3}}_{\text{Sulphate of soda.}} + \underbrace{\mathrm{Zn\,Cl}}_{\text{Chloride of zinc.}} + \underbrace{\mathrm{H}}_{\text{Hydrogen.}}$$

The products can be separated by crystallization; and from the mother-liquor, lime will precipitate hydrate of zinc, which can afterwards be substituted for metallic zinc, for the production of sulphate of soda from common salt.

Various other processes for the preparation of salt-cake have been adopted on a more or less extensive scale. In some of these, hydrochloric acid is also obtained; in others chlorine, or a mixture of this and hydrochloric acid; and in others, the chlorine is removed in combination with bases. One of the oldest of these methods consists in heating together in a reverberatory furnace a mixture of common salt and pyrites—bisulphide of iron. In this process, the sulphur of the bisulphide becomes oxidised to sulphuric acid, under the influence of heat, atmospheric air, and of sodium; and the sodium being at the same time converted into soda, combines with the acid produced. The chlorine of the common salt partly combines with the iron, and the other portion unites with the hydrogen of the water or steam evolved from the combustible materials employed to form hydrochloric acid. The heat being continued, the chloride of iron at first formed becomes decomposed; nearly pure chlorine is evolved, and sesquioxide of iron remains in admixture with the sulphate of soda. By lixiviating the mass with water, the sulphate of soda is dissolved; and by evaporating the solution, the pure salt may be obtained in crystals, or as an anhydrous mass. Mr. **Longmaid**, some years ago, proposed this method for the preparation of sulphate of soda for the alkali manufacturer, and at the same time of pure chlorine for the production of bleaching powder. He suggested that the chlorine might be freed from hydrochloric acid by bringing it in contact with a surface of wood, kept moist from the outside; and the gas from it, if to be used in the production of bleaching powder, must then be dried by any convenient method. The mixture of sulphate of soda and oxide of iron he directs to be employed, instead of the pure sulphate, in the preparation of black ash according to the usual process.

This plan is not likely to supersede the old method of manufacture; for, besides the great defect arising from the slowness with which the decomposition of the common salt proceeds, there is, according to **Dumas**, a considerable loss of sulphur during the process, owing to the incomplete oxidation of this element. This portion of sulphur is evolved as sulphurous acid in admixture with hydrochloric acid.

Protosulphate of iron has been used to a considerable extent for the conversion of chloride of sodium into sulphate of soda. This may be effected in two ways; firstly, by dissolving the copperas and salt together in water, when a double decomposition takes place, with formation of sulphate of soda and protochloride of iron as in the annexed equation:—

$$\underbrace{\text{Na Cl}}_{\text{Chloride of sodium.}} + \underbrace{\text{Fe O SO}_3}_{\text{Sulphate of iron.}} = \underbrace{\text{Na O SO}_3}_{\text{Sulphate of soda.}} + \underbrace{\text{Fe Cl}}_{\text{Chloride of iron.}}$$

The sulphate of soda may be procured in hydrated crystals—Na O SO_3, 10 HO—by exposing the solution to a low temperature; or, in an anhydrous state as an opaque precipitate, by concentrating the solution at the boiling point. In either case the chloride of iron remains in the mother-liquor.

The other process for the conversion of chloride of sodium into sulphate of soda, by means of sulphate of iron, consists in the calcination at a red heat, in a reverberatory furnace, of an intimate mixture of the two salts in the proportion of sixty parts of chloride of sodium to one hundred and forty of the iron salt. In this case, there is formed, at first, sulphate of soda and chloride of iron as above. By heat, however, the chloride is transformed, by virtue of the decomposition of water, into hydrochloric acid, which is disengaged, and into oxide of iron, which remains mixed with the sulphate of soda. There is also eliminated a little sulphuric acid and chlorine. **Dumas** states that the process may be rendered more productive of sulphate of soda, by mixing the two substances together in powder, and leaving the mixture for some days in a heap moistened with water, and afterwards heating to redness. This mode of manufacture of sulphate of soda is employed in the North of France.

Among the processes for the manufacture of caustic soda, that of Mr. **William Hunt** has been mentioned. It consists in the decomposition of sulphide of sodium by means of oxide of zinc or of copper, when there are produced caustic soda and sulphide of copper or zinc. The metallic sulphide thus obtained, he directs to be applied in the preparation of sulphate of soda, either by roasting so as to produce sulphuric acid in the ordinary manner, and causing this to act upon common salt; or by heating the sulphide to a temperature of about 400°, with exposure to the air, whereby the sulphide is converted into sulphate. The sulphate of copper or zinc thus obtained, after having been freed from the accompanying oxide or unaltered sulphide by lixiviation with water, is mixed with a solution of common salt, when there are produced sulphate of soda and chloride of zinc or of copper. The alkaline sulphate is separated from the metallic chloride by crystallization, and from the chloride remaining in the mother-liquor, oxides of zinc or of copper, in a condition to be used for the decomposition of more alkaline sulphide, is obtained by the addition to the solution of milk of lime.

The preparation of sulphate of soda and of chlorine for bleaching powder was carried on simultaneously at former periods. The process which was first adopted by the Messrs. **Tennant** and Company of Glasgow, consists in heating together a mixture of chloride of sodium, binoxide of manganese, and sulphuric acid in leaden vessels, when changes ensue, as represented in the subjoined equation:—

$$\underbrace{\text{Na Cl}}_{\text{Chloride of sodium.}} + \underbrace{2\ \text{Mn O}_2}_{\text{Binoxide of manganese.}} + \underbrace{2\ \text{SO}_3}_{\text{Sulphuric acid.}} = \underbrace{\text{Na O SO}_3}_{\text{Sulphate of soda.}} + \underbrace{\text{Mn O SO}_3}_{\text{Sulphate of manganese.}} + \underbrace{\text{Cl}}_{\text{Chlorine.}}$$

The whole of the chlorine of the common salt is therefore evolved in the pure state, while there remains a mixture of sulphate of soda, sulphate of manganese, and the excess of sulphuric acid employed. To this as much common salt is added as is necessary to saturate the free sulphuric acid, and the whole is heated in a reverberatory furnace. In this operation, the manganese and iron-salts are decomposed; and the sulphate of soda may then be withdrawn from the fused mass with water. It will be observed that in this process one half of the sulphuric acid employed is lost; and this being of greater value than the equivalent proportion of hydrochloric acid lost in the other methods of treatment, the plan has been generally abandoned.

Besides these sources of sulphate of soda, it is obtained also frequently from the mother liquors of common salt. When these solutions are sufficiently concentrated, a substance separates in flakes, which is a double salt composed of sulphate of soda and sulphate of lime. This is collected, washed with cold water to remove adhering chloride of sodium, and then treated with boiling water. The sulphate of soda now dissolves; and the solution, after being allowed to deposit, is decanted and evaporated to the crystallizing point or to dryness. The sulphate of soda in these liquors is probably formed by double decomposition of sulphate of magnesia and chloride of sodium.

Crude salt cake, prepared by the action of sulphuric acid upon common salt, usually contains from ninety-two to ninety-six per cent. of sulphate of soda, and, besides free sulphuric acid, chloride of sodium, minute quantities of other matters, as sesquioxide of iron, *et cetera*. A sample prepared at the works of JAMES MUSPRATT and Sons, Liverpool, was examined in the Editor's laboratory, and gave the following results :—

Sulphate of soda,	96·515
Sulphate of lime,	0·923
Sulphuric acid,	0·616
Chloride of sodium,	1·345
Sesquioxide of iron,	0·191
Water,	0·187
Insoluble matter, coal, *et cetera*,	0·130
Loss,	0·093
	100·000

NITRATE OF SODA—CUBIC NITRE—SODA-SALTPETRE.—*Nitrate de soude*, French; *Salpetersaures Natron*, German.—Nitrate of soda may be prepared artificially by saturating nitric acid with carbonate of soda, and evaporating the solution to dryness; by precipitating nitrate of baryta or of lime with sulphate of soda, allowing the solution to deposit the insoluble earthy sulphate, decanting the clear liquor, evaporating and allowing the nitrate to crystallize; and lastly by mixing solutions of nitrate of potassa and of sulphate of soda, when double decomposition succeeds, producing sulphate of potassa and nitrate of soda. The latter salt, being much the more soluble of the two, remains in the liquid after the former has crystallized, and may be obtained as already directed. The pure salt may likewise be obtained from the common variety, by dissolving the latter in the least quantity of boiling water, filtering the liquid whilst hot, and stirring the filtrate till quite cold. The crystalline deposit which forms during the last operation is transferred to a funnel loosely plugged with cotton, allowed to drain, and then washed by pouring on it cold water in small portions at a time, allowing each washing to drain off thoroughly before the succeeding edulcoration, and continuing the operation till the washings give no milkiness with nitrate of silver. The powder is then dried.

Properties.—Nitrate of soda crystallizes in transparent rhombohedral prisms; it has a cooling and bitter taste. Water dissolves it with great reduction of temperature; three parts at 60°, one part at 125°, and much less than its own weight at 212°, are required to dissolve one part of the salt. It becomes damp only in moist air; but, according to some chemists, deliquesces perfectly in an atmosphere saturated with watery vapor. When heated, it melts and evolves at first pure oxygen gas; afterwards the oxygen becomes mixed with nitrogen, and fumes of nitrous acid. It detonates with charcoal and other combustible bodies, but less violently than the corresponding salt of potassa. It is composed centesimally of—

	At. weight.	Centesimally.
1 Eq. of soda,	31	36·47
1 Eq. of nitric acid,	54	63·53
	85	100·00

Its chemical symbol is $Na\ O,\ NO_5$.

COMMERCIAL NITRATE OF SODA.—*Sources.*—This compound is not a manufactured product, but is found associated with other saline bodies distributed over various parts of the earth in the form of a mineral deposit, or as an efflorescence on the surface of the ground. Associated with nitrate of potassa, it is met with in Spain and in various parts of India; but the most remarkable deposit of this salt occurs in Peru, where a tract of country one league long and several broad, in all comprising, perhaps, fifty square leagues, is more or less incrusted with that substance. The existence of this salt in Peru has been known for about a century, and in 1820 some of it was sent to England; but the duty imposed was so high that it was not brought into the country. Between 1820 and 1830 several attempts were made to induce manufacturers to use the salt in England, America, and France; but it was not until 1831, that its real value as an article of commerce became generally known.

On the coast of Peru the land rises in a very precipitous manner to the height of about four thousand feet above sea-level; at this height the rocks shelve down a little into the country, and the view opens out on a plain of immense extent, varied only by slight undulations of the surface. These grounds, called the Pampas, are dry, arid plains, on which hardly a trace of vegetation is seen; plants of the cactus family even scarcely being able to maintain a struggling existence. No rain falls on these plains; and the deep blue of the sky or the bright glare of the sun is never obscured by a cloud; even the phenomenon of wind is hardly known; and the character of the locality is that of stillness, so profound indeed as to impress itself upon both man and beast.

From thirty to thirty-five miles from the coast, just before reaching the level ground of the Pampas, are found the deposits of nitrate of soda most esteemed for their purity and most easily procurable from their thickness. The depth of the layers varies from a few inches on the level plains to four, and even seven feet, on the slopes and hollows of the ground. The salt is found on the surface of the ground, or covered only to a very slight extent with a hard crust, consisting of a mixture of common salt and clay. This crust increases in thickness in some parts to four or five feet; and the crude nitrate or *nitrate caleche*, as it is termed, under the thick layers, is the material most sought after for its purity. The workable nitrate —being that found of sufficient thickness—occurs in patches of about five hundred yards, mean breadth; and the character and value of the deposit varies considerably even within the limit of a few hundred yards. From an examination of several samples, the crude material has been found to contain on an average from twenty-five to thirty per cent. of impurity; this consisting principally of common salt, but associated with small quantities of chloride of iron, sulphate of soda, sulphate of lime, and iodide of sodium, and in some specimens clay.

Purification.—It has already been observed that the purest layers of nitrate lie under a hard crust of earthy matter, mixed with chloride of sodium; this is so hard that it is usual to employ the aid of gunpowder in dislodging the material by blasting. The powder used for this purpose is a coarse material made on the spot from the nitrate of soda, charcoal, and sulphur; the charge, where the vein of salt and the covering is thick, will frequently be three hundredweight, and this will dislodge upwards of twenty tons of salt. The pieces thrown up are broken with hammers, and a selection is made of the purest specimens. The crude product obtained in the manner described is, however, very seldom found in such a condition of purity as to be capable of immediate application in the arts; and the great difficulty of getting the salt from the *officinos* or *lurks* to the coast, renders it imperative to purify the substance as much as possible in the localities that yield it. The process of purification usually adopted is, however, extremely simple, and is dependent on the difference in solubility between common salt—which is the principal foreign substance—and the nitrate of soda, at temperatures above the common.

The apparatus employed for this purpose consists of two dissolving vessels, a settling pan, and several crystallizing pans. The dissolving vessels are hemispherical pans of cast-iron, about six or seven feet diameter and three or four feet deep. They are dead-set in brickwork, and one fire plays round and between them. Into these vessels a quantity of mother-liquor, saturated with common salt from a preceding operation, is run, and a charge of nitrate calèche, consisting of fifteen quintals, is now thrown in, and the whole boiled for four or five hours, until the liquid is considered to be saturated with nitrate of soda. The solution is now ladled by hand into a settling pan, in which the liquid clarifies by subsidence. In a few hours the clear lie, still hot, is drawn off into shallow coolers, constructed of boiler-plate iron, and in these the nitrate of soda crystallizes out as the liquor cools. The crystals are shovelled out on to the ground, and dried by exposure to the sun, while the mother-liquor is made available for the solution of a further quantity of the crude material. The ordinary yield of crystals from fifteen quintals of nitrate calèche, is from eight to ten quintals, or about seven and a half hundredweight. A quantity of these dry crystals, sufficient for a load, is now introduced into two bags; these are slung on the back of a mule, and with this load the animal winds down the sides of the mountain to the sea-coast. The mother-liquors, after being used for several operations, become charged to a considerable extent with iodide of sodium, when that substance is a constituent of the crude material, but little iodine is obtained from this source, although, with proper management and utensils, the working might be made a profitable investment. The use of steam has been tried in purifying the crude nitrate, but with only partial success. The apparatus employed for this purpose consists in an iron vessel constructed in the form of an inverted cone, both ends being open. This vessel is filled with nitrate calèche and steam blown in through the bottom of the cone. The great solubility of the nitrate of soda in water, and its powerful attraction for that substance, induces its separation from the common salt, and a saturated solution of nitrate of soda, made by the condensed steam, flows out through the bottom of the cone. But owing to the necessity for introducing the crude material in lumps, a great portion of the soluble part in the interior of these is protected by the undissolved portion on the outside from contact with the steam, and as a consequence, a large amount of nitrate of soda is left undissolved; the loss from this source is the cause that little favor has been extended to the process.

One of the greatest sources of inconvenience in the purification and export of nitrate of soda is the want of pure water all along the sea-coast. On the Pampas a brackish water is obtained by boring for a few yards, and this, although not agreeable, is yet drinkable; but at Iquique, which is the port whence almost all the nitrate of soda is shipped, no drinkable water is to be found; the whole supply being derived from the distillation of sea-water. There are two large distilleries established to supply the want in this respect. The water obtained is, however, too expensive an article to be used in quantities sufficient for the healthy sustenance of animal life, and the mules employed in bringing down the nitrate of soda to the port, obtain a supply only by bringing it down with them from the mountains. Their privations in this respect, and the consequent injury to healthy life, is one of the greatest obstacles to the cheap supply of nitrate of soda.

This salt, obtained by the method described, is now usually supplied in commerce in a condition of great purity; the foreign matters, including water, or the *refraction*, as these are collectively termed in commercial circles, seldom exceeding seven per cent., and being more generally below six per cent. The impurities consist principally of common salt and water, the latter being attracted from the atmosphere; but a small proportion of sulphate of soda and lime is also found in it, with variable quantities of sand. No other substance can be detected in the commercial article in sufficient quantity to influence its value; but the actual value of the salt is so high that it becomes a matter of importance to detect the proportion of impurities, however small in amount. The following rapid and effectual method of doing so is recommended for those who are unacquainted with the more delicate manipulations of analytical chemistry:—A small quantity of the sample—say one hundred grains—is weighed out, and dried in a water or oil bath until it no longer loses weight. The difference will give the amount of water. Another quantity, about one hundred grains, is weighed out and dissolved in pure distilled water, a few drops of pure nitric acid added, and the liquid made up to a thousand grain measures with water. About a hundred grain measures of this solution are transferred to a glass tube, and tested by comparison with several dilute standard solutions of common salt, contained in similar tubes, by means of a solution of nitrate of silver. The amount of cloudiness in the precipitate is observed with great nicety, and by comparison with the precipitate observed in the standard solutions of common salt, the per centage of this substance in the sample tested may be ascertained with much exactness. A very important point to be observed in this method of testing, is to have the solutions so dilute that only a distinct cloudiness shall be produced by the addition of the silver salt. By attention to this matter very minute differences are readily observed.

The per centage of sulphate of soda is determined by a similar method, using hydrochloric acid to acidify the solution of the sample in place of nitric acid, and employing dilute standard solutions of sulphate of soda, to compare with the sample. The precipitation is effected with a few drops of a strong solution of chloride of barium; but while the indications of chloride of sodium afforded by a silver salt are immediate, the cloudiness produced by adding chloride of barium to sulphate of soda, contained in a large quantity of solution of nitrate of soda acidified, is not immediately perceptible to its full extent when the solutions are weak. It is therefore advisable to compare the results obtained with the standard solutions, and the sample tested, only after the lapse of some hours. With this simple precaution the estimation of the per centage of sulphate of soda is effected with great accuracy by the method described.

The sand is estimated by dissolving the salt in water, filtering the solution, and after thoroughly washing the filter paper, calcining the insoluble portion. The per centage of water, chloride of sodium, sulphate of soda, and sand, being subtracted from one hundred parts of the commercial sample, will give the per centage of pure nitrate of soda to a very close approximation.

Various methods of estimating the amount of nitrate by a direct process are practised; but accurate results are only obtainable by the exercise of considerable skill in analysis. These are described under the article, Nitrate of Potassa, page 735; and the same description will apply equally well to the estimation of nitrate of soda, with the simple alteration of the equivalent weight of the former to that of the soda salt; that is, by putting the equivalent weight of nitrate of soda —85—in place of 101, the equivalent of nitrate of potassa.

Nitrate of soda is distinguished from potassa-nitre by its deliquescent property, a character that renders it quite inapplicable to some of the purposes for which the latter is employed, as for instance to the manufacture of gunpowder. It is extensively employed in the manufacture of nitric acid, owing to its cheapness, and also because it affords nearly ten per cent. more nitric acid than the corresponding potassa salt. Its principal consumption is in the production of nitric acid, and as a vehicle for conveying oxygen to the sulphurous acid of vitriol works, whereby it is converted into sulphuric acid. Of late years it has been used largely as a manure. The subjoined are analyses of the commercial salt; but besides the ingredients named, Lembert found also small quantities of iodide of sodium and iodate of soda:—

	Hoffstetter.	Lecanu.	Wittstein.
Nitrate of soda,	94·29	96·70	99·63
" potassa,	0·43	—	—
" magnesia,	0·86	—	—
" lime,	—	trace	trace
Chloride of sodium,	1·99	1·30	0·37
Sulphate of potassa,	0·24	trace	—
Water,	1·99	2·00	—
Insoluble matter,	0·20	—	—
	100·00	100·00	100·00

The following table gives the amount shipped from Iquique, and which may be assumed to be the yield of the saliferous grounds of Peru.

SUMMARY OF NITRATE OF SODA SHIPPED AT IQUIQUE, JANUARY 20, 1859, TO DATE, IN QUINTALS:—

For	1857.	1858.	1859.
England,	143,873	109,809	204,775
France,	127,767	138,465	197,980
Hamburg,	69,810	48,601	158,057
Orders,	141,220	204,927	175,957
United States,	13,600	24,900	29,780
Austria,	7,720	—	—
Holland,	6,038	—	11,866
California,	3,577	—	6,200
Spain,	20,300	—	—
Sardinia,	2,225	—	11,570
Chili,	—	11,666	—
Peru,	—	155	103
Total,	536,150	538,523	796,288

Phosphate of Soda.—This salt has long been known as one of the constituents of urine, having been discovered in that fluid by Hellot in 1737. It was not, however, sufficiently distinguished from other salts till a much later period, when it was examined and analysed by Proust, Rouelll, and Klaproth.

It is most conveniently prepared by adding carbonate of soda to the solution of acid phosphate of lime, obtained by treating bone earth with sulphuric acid. The liquor should be maintained at a boiling temperature; and the carbonate of soda must be added as long as effervescence continues, or until the solution has an alkaline reaction. The effervescence is due to the escape of carbonic acid; the soda unites with the free phosphoric acid and with a portion of the acid of the superphosphate, while at the same time phosphate of lime, or a mixture of this and carbonate of lime, is precipitated. This insoluble matter is removed by filtration, and the liquor is then boiled down and allowed to crystallize. To obtain an additional quantity of the salt from the mother-liquors, it is necessary first to examine if these manifest an acid or an alkaline reaction. In the first case, more carbonate of soda must be added to restore the alkaline reaction, and the liquor again evaporated and set aside to crystallize.

If, on the contrary, too much carbonate of soda has been added originally, the crystals obtained will require to be washed, a fresh portion of the acid phosphate of lime added, the solution evaporated, and again allowed to crystallize. To obtain good crystals of this salt, it is necessary that a slight excess of carbonate of soda be present. In operations on the large scale, when it may be advisable to economize the phosphate of lime, FUNCKE directs that the precipitate obtained on adding carbonate of soda be dissolved in nitric acid; sulphate of soda is then added, and the nitric acid is removed by distillation. The residue is then treated with water, when a solution of phosphate of soda is obtained, with a deposition of sulphate of lime.

Properties.—Phosphate of soda crystallizes in beautiful transparent colorless rhombohedral prisms terminated by four converging planes. The crystals are represented by the formula, $\mathrm{2\,Na\,O,\ HO,\ PO_5,\ 24\,HO}$. Their taste is cooling and mildly saline, not unlike common salt. They are soluble in four parts of water at 60°, and in two of boiling water. Exposed to the air, the salt undergoes efflorescence, but this takes place only at the surface; beneath, the form and transparency are preserved. Heated, the crystals fuse in their water of crystallization, and then water passes off. But one equivalent of water for every two equivalents of soda is obstinately retained, and cannot be expelled, except at a red heat. When two equivalents are driven off, the salt acquires peculiar properties, different from those it originally possessed, being converted into pyrophosphate of soda. The cause of the change of property, according to GRAHAM, is that in the common or rhombic phosphate, the acid is united in the proportion of one equivalent with two of soda, and one of water in the capacity of a base, constituting a tribasic phosphate of soda and water; and that when the basic water is expelled by a red heat, the salt becomes a bibasic phosphate, composed of one equivalent of acid and two of soda, and, therefore, a totally different compound. Phosphate of soda, consisting of two equivalents of soda, one of acid, and twenty-five of water—$\mathrm{2\,Na\,O,\ HO,\ PO_5,\ 24\,HO}$—contains—

		Centesimally.
Soda,	62·6	40·00
Phosphoric acid,	71·4	45·62
Water,	22·5	14·38
	156·5	100·00

The uses of phosphate of soda are principally in medicine, and in the laboratory of the chemist.

Physiological Effects.—This salt is an excellent saline cathartic, equal to the most esteemed of the neutral salts in this respect, and superior to them in the mildness of its taste. As a purgative, it is employed in the diseases of children and delicate persons in preference to other saline substances, on account of its slight taste and mild action. It is well adapted for febrile and inflammatory disorders. It is one of the substances which have been applied in cholera, to restore to the blood its deficient saline matters. On account of the phosphoric acid which it contains, it has been supposed to be especially applicable in those diseases in which there is a deficiency of phosphate of lime in the bones. It has also been administered in diabetes.—*Pereira.*

Ordinary phosphate of soda—the variety above described, is known in combination with one equivalent only of water, the salt having this formula, $\mathrm{2\,Na\,O,\ HO,\ PO_5}$; and also with fifteen equivalents of water, represented by $\mathrm{2\,Na\,O,\ HO,\ PO_5,\ 14\,HO}$.

Pyrophosphate of Soda—$\mathrm{2\,Na\,O,\ PO_5}$—obtained by heating the simple phosphate, has already been mentioned. This is also known in combination with water the crystallized salt being $\mathrm{2\,Na\,O,\ PO_5,\ 10\,HO}$. *Metaphosphate of Soda*—$\mathrm{Na\,O,\ PO_5}$—is obtained by heating the pyrophosphate, and according to the degree of heat used in its formation, appears in three different forms which, though the same in composition, possess different properties, as if the pyrophosphoric acid passed by a gradual transition into metaphosphoric acid.

Phosphate of Soda and Ammonia, or Microcosmic Salt, is a compound much used in the chemical laboratory in blowpipe examinations. It is prepared by dissolving six parts of common phosphate of soda, and one part of chloride of ammonium, by boiling with two parts of water. As the solution cools the double phosphate separates in crystals, and by a second crystallization is freed from adhering chloride of sodium. In this salt one equivalent of soda in the common phosphate is replaced by ammonia, and the crystallized salt has the composition, $\mathrm{Na\,O,\ NH_4\,O,\ HO,\ PO_5,\ +\ 8\,HO}$.

When subjected to the action of heat the ammonia escapes with the water of crystallization, and a compound of similar composition to borax remains, that is to say, a compound which contains both a free acid and a readily fusible salt. It is preferred in some cases to borax as a solvent or flux in blowpipe operations, the beads which it forms with many substances being more beautifully and distinctly colored than those of borax.

BORATES OF SODA.—There are several combinations of boracic acid and soda, such as the monoborate, biborate, and quadraborate of the alkali; but the most important of them is the biborate, a salt which has been already described fully in Vol. I., page 346, *et sequitur.* Allusion may, however, be made here to another source whence boracic acid and biborate of soda may be made. This is the biborate of lime—boracite—which has been discovered in large quantities on the Western coast of America, and called after its discoverer, HAYES, *Hayessine.* It is met with in the Peruvian province of Tarapaca, near the port of Iquique, and in the same locality as that which produces the nitrate of soda in such abundance. It is imported in moderately large quantities into Liverpool. It is in the form of botroidal lumps, which, when broken, appear in loose fibres or scales of a nacreous white color, intermixed or incrusted with crystals of carbonate of lime and finely divided white clay. Biborate of soda may be prepared from this mineral by reducing it to an impalpable powder, and dissolving in ordinary hydrochloric acid, filtering or clarifying the solution by subsidence, and adding carbonate of soda to the menstruum. The lime is separated by this process as carbonate, whilst biborate of soda is produced, and may be obtained from the filtrate or supernatant liquid by evaporation, *et cetera.*

CARBONATE OF SODA.—This important salt is met with in nature under various conditions, but never in a state of purity. It exists in the soda lakes of Egypt and

Hungary, and in other mineral waters, though not in sufficient quantities to remunerate for its extraction. KUHLMANN and VOGEL found it in admixture with the sulphate of the same base in an efflorescence on the walls in several towns, and considered its production to be owing partly to the presence of soda salts in the limestone used in the preparation of the mortar, and partly to the soda in the coal with which the limestone had been burned. In plants growing on the sea-shore oxalate of soda exists, and when these are burned, the oxalate, losing carbonic oxide, becomes carbonate.

Preparation.—In a state of purity, carbonate of soda is most conveniently prepared from the bicarbonate. To obtain it, the latter salt is washed with cold water until the filtrate, after being acidified with nitric acid, is not rendered turbid by chloride of barium or nitrate of silver. The washed salt is then dried, and by gentle ignition one half of the carbonic acid is expelled, and the pure neutral carbonate remains.

The bicarbonate of soda used should be as pure as can be obtained, and must, of course, be completely soluble in water. That most suitable is obtained by passing carbonic acid into a strong aqueous solution of crystallized carbonate of soda.

The process recommended by GAY-LUSSAC, for the preparation of pure carbonate of soda, is also a good one, and less troublesome than the former. He washes the ordinary commercial crystals of this salt with cold water; dissolves them in hot water, and cools the solution rapidly by surrounding it with cold water, stirring it all the time with a spatula, so that small crystals may be formed. These are to be collected on a funnel, and after the mother-liquor has been drained off, washed with cold water till the drainings mixed with excess of nitric acid no longer give a precipitate with nitrate of silver. The crystals are then to be dried, and when heated to low redness, the pure anhydrous carbonate remains.

Properties.—Anhydrous carbonate of soda is white, translucent, of specific gravity 2·4649; it is very soluble, and much more so in hot than in cold water; its reaction is alkaline, and its taste slightly caustic, much less so than the corresponding salt of potassa.

The annexed table shows the amount of the anhydrous salt contained in *solutions of different gravities at a temperature* of 59°:—

Specific gravity.	Per cent.	Specific gravity.	Per cent.
1·1816	14·880	1·0847	7·440
1·1748	14·508	1·0802	6·768
1·1698	14·136	1·0757	6·396
1·1648	13·764	1·0713	6·324
1·1594	13·392	1·0669	5·972
1·1549	13·020	1·0625	5·580
1·1500	12·648	1·0578	5·208
1·1452	12·276	1.0537	4·836
1·1404	11·904	1·0494	4·464
1·1356	11·532	1·0452	4·092
1·1308	11·160	1·0410	3·720
1·1261	10·788	1·0368	3·348
1·1214	10·406	1·0327	2·976
1·1167	10·044	1·0286	2·504
1·1120	9·672	1·0245	2·232
1·1074	9·300	1·0204	1·850
1·1028	8·928	1·0163	1·488
1·0982	8·556	1·0121	1·116
1·0937	8·184	1·0081	0·744
1·0892	7·812	1·0040	0·372

Carbonate of soda forms several crystalline combinations with water. When a saturated aqueous solution is evaporated at a boiling temperature, small crystals are deposited containing an equivalent of water, and consequently represented by the formula, $Na\,O,\ CO_2 + HO$. Monohydrated crystals are also formed when the ordinary commercial crystallized carbonate is kept in solution for some time in its own water of crystallization, or evaporated between 167° and 190; and when commercial crystals are exposed to the air at a temperature of 100°, the monohydrated carbonate remains as an effloresced mass. The form of the crystals is that of a four-sided table. It does not melt when heated, but at a temperature from 188° to 212° loses the whole of its water. Exposed to the air, it gradually absorbs moisture, to the amount of six or seven equivalents.

When ordinary crystallized carbonate is exposed to the air at a temperature of 54°, an effloresced salt remains, containing five equivalents of water, $= Na\,O,\ CO_2 + 5\,HO$. This may also be obtained in crystals by melting the same salt and maintaining it at a temperature of 92°. PERSOZ states that crystals having this composition were accidentally obtained at the Buxweiler soda works, in transparent rhombic octohedrons, which effloresced slightly in the air, and when dissolved in water, and evaporated at 86°, again yielded the same salt. According to MITSCHERLICH, a solution of protosulphide of sodium exposed to the air, and frequently also a mixed aqueous solution of chloride of sodium and carbonate of potassa, yield crystals containing six equivalents of water, $Na\,O,\ CO_2,\ 6\,HO$.

Crystals of carbonate of soda have also been obtained containing eight equivalents of water, $Na\,O,\ CO_2,\ 8\,HO$, in the form of rectangular prisms, terminated by four-sided summits. These are produced when the ordinary crystallized salt cools from a state of fusion, or from a saturated aqueous solution at a particular temperature.

Common commercial crystallized carbonate of soda contains a still greater proportion of water than the salt last named. These crystals are a combination of one equivalent of carbonate of soda with ten equivalents of water, and are consequently represented by the formula $Na\,O,\ CO_2,\ 10HO$. They are formed from a moderately concentrated solution, at a temperature below 92°. Their crystalline form is that of the oblique prism.

When gently heated this salt fuses, monohydrated carbonate crystallizes out, and the residual liquid, although containing more than ten equivalents of water to each equivalent of carbonate, solidifies at about 92°. When exposed to the air it loses a portion of its water, and becomes covered with an efflorescence containing eight equivalents of water.

NATIVE SODAS.—In France, Spain, and other countries where common salt is scarce, or where the duty upon this article is so great as to prevent its conversion into carbonate of soda, plants and alkaline waters are extensively consumed for the soda they contain. Besides these two great sources, carbonate of soda also occurs mineralized in some countries, though not in any great quantity, and is generally the residue of the evaporation of alkaline waters.

In Egypt, in the desert of Thaiat, to the West of the Delta, there is a pit four leagues long and a quarter of a league wide, which, during the winter months, becomes filled to the height of five or six feet with violet-colored water. In the summer this water evaporates, and an incrustation of carbonate of soda remains, half an inch in thickness. At Shegedin, in Little Curnania, a province of Hungary, Werner found carbonate of soda as an efflorescence on the ground, and some years ago it was extensively collected and purified. The commercial demands for soda were supplied formerly, principally by the combustion of marine vegetals. These contain the soda, according to Dumas, as oxalate, and by calcination this is converted into carbonate of soda. The plants, after being dried in the air, are burnt in rude furnaces, at a temperature just sufficient to cause the ashes to enter into a state of semifusion, so as to concrete on cooling into moderately compact cellular masses. The substance so obtained is known under various names, according to the country whence procured, and the kind of plant consumed for its production. Among these may be mentioned the *barilla* of Spain, *kelp* of Scotland, *varec* of Brittany and Normandy, *blanquette* of Frontignan and Aiguemorte, and the *salicor* of Narbonne. The soluble portion of these ashes consists of carbonate, sulphate, and hyposulphate of soda, sulphide, iodide, bromide, chloride, and ferrocyanide of sodium, and sometimes also the corresponding compounds of potassium ; and the matters insoluble in water are carbonate and phosphate of lime, sulphide of calcium, magnesia, alumina, silica, sulphide of iron, and charcoal. Of the several varieties, *barilla*, known also in commerce as Alicante soda, Carthagena soda, and Malaga soda, is by far the most valuable. It contains from fourteen to twenty per cent. of soda in the state of carbonate. It has a greyish-blue color, and when exposed to the air for some time effloresces at the surface. It is hard and difficult to pulverize, and has a pungent alkaline taste. The plant yielding this ash is the *salsola soda;* it is carefully cultivated on the coasts of Spain for the purpose of this manufacture. The following table shows the composition of various kinds of ash, as given by Girardin, Richardson, and others :—

Constituents.	Alicante.	Cherbourg.	Cherbourg.	Unknown.	Unknown.	Spain.	Villette.	Granville.
Sulphate of potassa,	—	22·19	42·54	18·80	22·00	15·85	20·35	13·50
Chloride of potassium,	—	16·00	19·64	—	—	10·55	10·53	15·60
Chloride of sodium,	65·00	45·78	25·38	73·20	68·00	68·35	54·11	65·68
Carbonate of soda,	2·00	9·53	3·71	6·00	6·00	traces	13·76	·22
Sulphate of lime,	—	—	—	—	—	1.10	—	—
Insoluble matters,	3·00	1·50	·73	—	—	—	—	—
Iodine compounds,	—	traces	traces	traces	traces	—	traces	traces
Sulphate of soda,	30·00	—	—	—	—	—	—	—
Water,	—	5·00	8·00	2·00	4·00	4·00	1·25	5·00
Loss,	—	—	—	—	—	·15	—	—
	100·00	100·00	100·00	100·00	100 00	100·00	100·00	100 00

Kelp, which was formally prepared on a considerable scale on the coasts of Ireland and the Western coasts and islands of Scotland, is greatly inferior in value to *barilla*. This is the residue of the combustion of seaweeds and various species of *fuci*, and similar plants. Its composition is very variable, not only as regards the proportion of alkaline carbonate, but of the other constituents ; and hence the uncertainty that attended its employment in some of the chemical arts, and particularly in the manufacture of crown glass. Two specimens—the first from Heisker, the second from Rona, both in the Isle of Skye—analysed by Ure, gave the following results :—

Soluble	Sulphate of soda,	8·0	19·0
	Soda as carbonate and sulphide,	8·5	5·5
	Chlorides of potassium and sodium,	36·5	37·5
		53·0	62·0
Insoluble	Carbonate of lime,	24·0	10·0
	Silica,	8·0	—
	Alumina, with a little oxide of iron,	9·0	10·0
	Sulphate of lime,	—	9·5
	Sulphur and loss,	6·0	8·5
		100·0	100·0

The native sodas obtained in France are distinguished under various terms, according to the district where extracted. The most valuable is that known as *salicor* or *Narbonne soda*, which is the residue of the combustion of the *Salicornia annua*. It contains from fourteen to fifteen per cent. of the alkaline carbonate. Another kind, also valuable, is *blanquette* or *aiguemorte soda*, extracted from plants growing on the coasts, among which the most important are the *Salicornia europœa*, the *Salsola tragus*, the *Atriplex portulacoides*, the *Salsola kali*, and the *Statice limoneum*. The first-named of these yields the most soda, and all contain abundance of common salt. The amount of carbonate of soda in *blanquette* varies from three to eight per cent. *Varec* or *Normandy* soda, like *kelp*, is the ash of plants belonging to the species *fuci*. This is the least valuable of the French native sodas, but it contains much sulphates of soda and potassa, chlorides of sodium and potassium, and a little iodide of sodium. It is principally extracted for the sake of its potassa salts, and is used in the manufacture of glass and saltpetre. It is also valuable as a source of iodine. The commercial demands for soda are now supplied almost exclusively by an artificial method of production. Barilla and kelp are used to a small extent in the soap manufacture, as a substitute for chloride of sodium, and in Scotland sea-weeds are still consumed as a source of potassa and of iodine. For the extraction of these the lie obtained from the ash is evaporated, when the potassa and soda salts separate one after the other, and the mother-liquor, distilled with sulphuric acid and peroxide of manganese, yields the iodine.

Generally, the ash of sea-plants, compared with that of those growing on the shore, is not rich in carbonate of soda, but contains much potassa. This fact is not, however, without exceptions, for in the various species of *fuci* soda largely predominates, and the fucoidal plants are, doubtless, also the principal sources of iodine in those ashes.

Artificial Soda.—Soda Ash.—White Ash.—The production of artificial soda is now one of the most important branches of manufacturing chemistry, although the art was, little more than half a century ago, almost entirely unknown. It may indeed be averred, without fear of contradiction, that since the first application of chemical science to manufacturing operations, few discoveries have been made having such an important bearing, whether considered in relation to social life, to commerce, or to the progress and successful prosecution of the useful arts, as that of the production of carbonate of soda from common salt. It would, indeed, be difficult to exaggerate the immense importance of this manufacture; and probably no more striking proof of this can be given than the enormously increased consumption of this salt since its production at a moderate cost was effected.

The manufacture of soap and of glass; the fictile arts, as well as those of bleaching and dyeing; the production of paper; many metallurgical operations, *et cetera*—are dependent for their successful prosecution upon a supply of carbonate of soda, and the various other substances obtained as by-products in the manufacture; and to meet the consumption of this article, the transformation of chloride of sodium or common salt into carbonate of soda is almost entirely depended upon.

Historical Notice.—It has been already observed that the introduction of artificial soda dates only from a very recent period. It has also been previously mentioned that of all the varieties of native soda, that known as *barilla* is by far the most valuable, containing twenty-five to thirty per cent. of the carbonate. The plant yielding this ash grows most luxuriantly on the coasts of Spain, and was formerly cultivated on a most extensive scale for the purposes of this manufacture; and the ash was produced so abundantly as to supply, not only the native demand, but also that of other countries where either the plants yielding soda were scarce, or if a large quantity of ash was obtained, the amount of soda contained in it was comparatively small.

While it thus happened that other nations were almost entirely dependent upon Spain for a supply of soda, Great Britain produced large quantities of native soda under the form of *kelp*, the manufacture of which was carried on at a very early period on the North and West coasts of Ireland, and later on the Western shores and islands of Scotland. This branch of trade was especially brisk at the commencement of the present century when, to meet the exigencies of the war, high duties were imposed upon the Spanish barilla. The annual rental of the kelp shores of the island of North Uist alone amounted at this time to seven thousand pounds; and at one period the entire quantity of *kelp* produced in Scotland, and its adjacent islands, was estimated at more than twenty-five thousand tons annually. Still, the quantity of native soda thus obtained was not sufficient to supply the demands of commerce; and even in 1834, some years after the introduction of artificial soda, barilla was imported to the amount of upwards of twelve thousand tons. But more especially was France dependent upon Spain for supplies of native soda; and when at the time of the French revolution of 1789, during the cessation of the commercial intercourse between France and Spain, the importation of barilla was suspended, the National Convention, incited by the proposition of a manufacturer of the name of CARNY, made, in a special proclamation, an appeal to the chemists of France to devise a process by which common salt might be rendered available as a source of soda, and to lay before them whatever plans they knew or could devise for the preparation of soda.

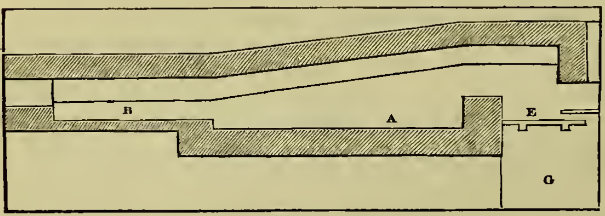
Not only was the importation of barilla discontinued, but the supply of potassa was also greatly diminished at this period. All the potassa that could be obtained in France was immediately applied to the production of saltpetre to be consumed in the fabrication of gunpowder; and those branches of trade requiring for their prosecution large supplies of alkali—either potassa or soda—were almost completely at a stand still. But necessity is ever the mother of invention; and the republic mastered the difficulty by an unprecedented development of internal power. To the appeal of the Convention due response was made, and numerous plans were proposed; but of all the processes communicated to the committee intrusted with the examination and execution of the various proposals, the only one deemed likely to be advantageous was that of LEBLANC, and the justness of this decision has been ratified by fifty years' experience; no essential improvement having since been made in the process. The first establishment for prosecuting the manufacture on a large scale, was erected in 1804 at Saint Denis by LEBLANC, and was carried out by him and his partners, DIZÈ and SHÉE. The great French chemist, after having spent all his means in perfecting his plan, was neglected by the government of his own country, and though handsomely rewarded by the British government, at last died in an hospital. In Greece and at Rome statues have since been erected to his memory.

The valuable properties possessed by carbonate of soda were too well known, even at an early date, in England, to allow experimenters to remain idle. In a patent granted to Dr. BRIAN HIGGINS *as early as* 1781, the Editor finds that he started with common salt, which he decomposed into sulphate of soda and hydrochloric acid by oil of vitriol, in the manner described under SULPHATE OF SODA. The dry sulphate or salt cake obtained was put into a reverberatory furnace, with one-eighth of its weight of coal, and heated till the ingredients were melted, and the sulphate reduced to the state of sulphide. At this stage twice its weight of lead was introduced, and when the metal was melted, the whole was stirred with an iron rod until the sulphur united with the lead, and the fused caustic soda floated in a distinct layer over the surface of the sulphide of lead. The furnace was then tapped to allow the alkali to flow out.

The great expense attending this plan, arising from the high price of lead, *et cetera*, rendered it valueless as a commercial process; but in the same patent HIGGINS states *that iron introduced into the furnace, or other metallic oxides, may be used equally well.* Here, therefore, is clearly developed the principle of LEBLANC'S process, who merely replaced *the oxide of iron by oxide of calcium* or lime. Higgins, therefore, may be considered *the inventor* of the process.

Leblanc's process, is substantially that practised in Great Britain at the present day. Its introduction into this country was, however, effectually prevented until a considerable period after it began to be adopted in France, by the enormously high duty imposed upon salt, amounting, from the year 1805 until about 1822, to fifteen shillings per bushel, or about thirty times the cost of the salt. Shortly after the repeal of this impost, the manufacture was commenced on a considerable scale in England by Mr. James Muspratt of Liverpool—*vide* Soap, page 872. Until the year 1830, the soda produced, which was almost wholly consumed in the soap manufacture, was disposed of in the crude condition, under the form of *black ash.* After that period the carbonate of soda was extracted from the black ash produced by lixiviation, and sold, as at present, as a white or soda ash. For about six years after the commencement of the manufacture, the trade remained almost entirely in the hands of the Editor's father. In the year 1836 an important improvement was effected in the carrying out of the process, by the introduction, by Mr. Gossage, of an apparatus for condensing the gaseous hydrochloric acid eliminated during the conversion of the common salt into sulphate of soda.

Fig. 516.



Many other improvements have been subsequently made, tending to render the process more complete and economical. These will be described in detail in the following pages. The first important operation in the manufacture—the conversion of chloride of sodium into sulphate of soda—has already been fully discussed. The next operation in the process is the production of *black ash.*

Black Ash.—Ball Soda.—The materials used in the production of this ash are perfectly dry sulphate of soda, charcoal, or small coal—slack—and carbonate of lime, either in the form of common limestone or as chalk. These substances require to be brought into a state of fusion together, and this operation is the most important part of the whole soda process. The details of the furnace arrangements at present in use for this operation are shown by the annexed drawings. Fig. 516 is a longitudinal section; Figs. 517, 517½ a plan; and Fig. 518 an end elevation. The furnace is similar in construction to a common reverberatory; but its floor, or *bed,* is divided into two parts, A and B—Fig. 516—B being raised half a brick above A. The former, or that farthest from the fire, is termed the *preparatory* bed, and upon this the materials are first placed and heated to low redness, so as to avoid cooling the furnace; the mass is often indeed in a state of partial fusion before its removal to the other hotter portion of the furnace bed, A. The latter is called the *fluxing* bed, and here the material is speedily brought to a liquid condition; the floor of A is lined internally with the most refractory fire-bricks that can be procured; it is not necessary to be so particular in respect to the floor of B. The arched roof is likewise built with fire-brick; E is the fire space, G the ash pit, and F the flue leading to the chimney.

When economy of space is a matter of much moment, the opening to the fire space is on one side of the furnace, and the bars reach across; but when it can be allowed, it is preferred to have two sets of fire bars, as shown in Figs. 517, 517½, and 518, and to fire the furnace at the end.

There are two openings into the furnace, C and D, furnished with doors partially supported with weights passing over pullies.

Fig. 517.

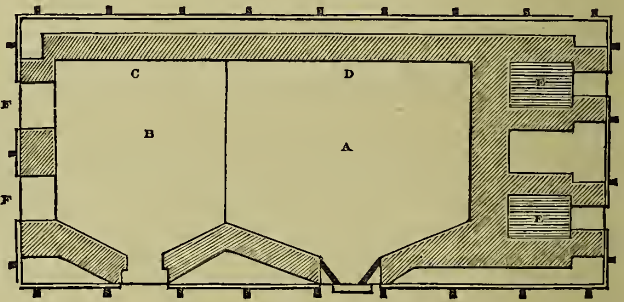
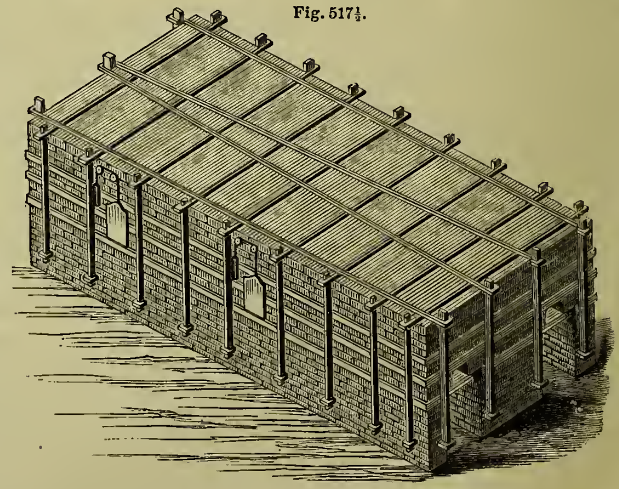


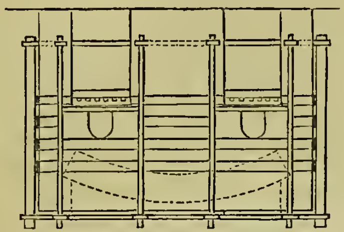
Fig. 517½.



The walls of the furnace at c and d are bevilled off on the inside, so as to render the furthest parts of the furnace readily accessible by means of the iron rakes and utensils used in working it.

Immediately in front of the openings, c and d, is suspended from the top of the furnace a stout iron rod, with a depression in the centre, so that the heavy rakes used may be supported upon it as a fulcrum.

Fig. 518.



The furnace walls are strengthened by iron plates, and firmly bound together by iron rods, as seen in the plan and end elevation.

The furnace having been heated to a suitable temperature, a charge, usually consisting of three hundredweights of sulphate of soda, three to three and a quarter hundredweights of crushed limestone or chalk, and two hundredweights of small coal, called *slack*, roughly mixed together, is then thrown on to the upper bed, A, and spread over it, so as to be evenly exposed to the flame of the furnace. A most important consideration is to have the ingredients of the mixture in proper proportions; although in compounding it, manufacturers may advantageously vary the amount of the ingredients, according to the purposes to which the black ash is to be applied. For instance, it is in some cases desired that the black ash produced should yield a considerable proportion of caustic soda, whereas in others, especially when the object of the manufacture is the production of soda crystals, the presence of caustic soda in large quantity is the occasion of great inconvenience.

It is a most difficult task to lay down precise rules for the guidance of the practical man in such cases, owing to the great difference in the materials used by different manufacturers. If the carbonate of lime employed be very fine, the proportions directed to be employed by Leblanc yield a good black ash. These are a thousand parts each of dry sulphate of soda and chalk, and five hundred and fifty of charcoal.

Wood charcoal can rarely be obtained cheaply enough to be used for this purpose, and small coal, such as leaves but little ash, is substituted for it, in which case the quantity used should then be two-thirds of the weight of the salt cake, or even more.

If all the materials taken were perfectly pure the proportions required would be—of sulphate of soda forty-one parts, of carbonate of lime forty-four, and of charcoal fifteen. This accords with the explanation of the process of decomposition given by Dumas; but his theory, as will be shown presently, has been more than once called in question. The proportions of salt cake and limestone or chalk employed, are properly one hundred parts of the former to one hundred and five, or one hundred and ten, or even one hundred and twenty of the latter; while, as to the proportion of coal, probably not two manufacturers in this country use the same. Ure recommends ten parts of salt cake, from eleven to twelve parts of chalk or limestone, and five parts of coal; and in a large manufactory near Liverpool, the proportions taken are, thirteen parts of salt cake, nine and a half parts of coal, and fourteen parts of limestone. Some chemists recommend that the materials should all be reduced to coarse powder, and afterwards most intimately mixed by sifting together. This is an unnecessary expense and waste, as the decomposition proceeds quite as successfully when the materials are simply broken into small fragments and mixed in that state.

The operation of fluxing is carried on in the following manner:—The furnace having been properly heated, the charge, differing in quantity according to the dimensions of the furnace, is thrown in upon the preparatory bed, spread evenly over its surface, and when it has become hot, transferred to the fluxing bed by means of an iron spatula or *slice*, shaped somewhat like an oar. The door of the fluxing bed is then closed, so that the heat may exert its full power, and a second charge is immediately placed upon the preparatory bed.

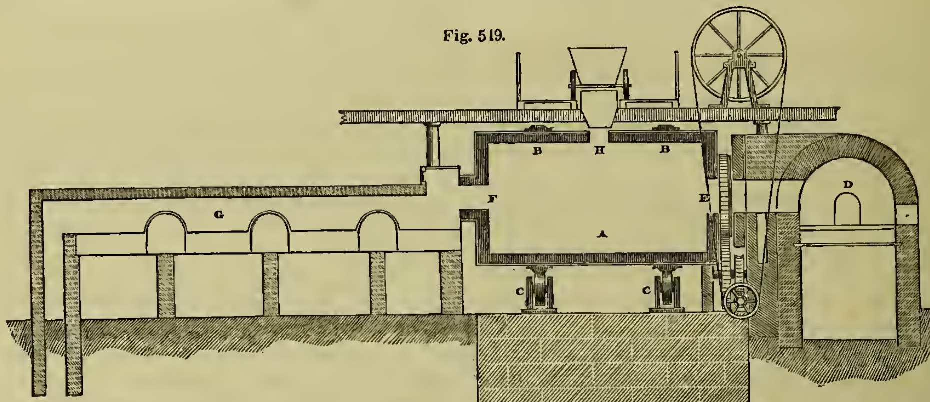
In a short time the charge upon the fluxing bed begins to soften at the surface and form into clots; it should then be turned completely over by the slice, and a fresh surface exposed, until the whole mass appears to have the consistence of dough. Jets of inflamed sulphide of hydrogen and carbonic oxide gases now issue from the various parts of the mass, and the whole should be continually worked about with the slice and an iron rake, so as to equalize the mass, and continually expose fresh surfaces to the action of the fire. When the jets of flame begin to disappear the mass is raked out into iron barrows, each capable of holding a single charge, in which it is allowed to solidify, and in this state it is termed *a ball*. In a furnace of the dimensions above given, the weight of each charge would be about seven hundredweight. Nine of these, the weight of which after decomposition will be about five hundredweight, may be introduced and withdrawn in eight hours, or twenty-seven in twenty-four hours. This is, indeed, the quantity usually worked in that period, but a still greater number of balls may be produced in the same time. The Editor has known nine charges to be introduced and completely decomposed in five and a half hours, and it is important to notice that the black ash so produced yielded its soluble portion with far greater ease than a ball that has remained in the furnace some minutes longer. It is, indeed, important that black ash should be withdrawn from the furnace the moment decomposition is completed, for in this case the mass, after solidification, remains so porous that the soluble portion may be extracted with colder water, and in a shorter period of time, than when closer and heavier black ash is produced. This is one of the characteristics of good black ash; another is that it should contain *no* sulphate of soda, and more especially should it be free from sulphide of sodium. It should be of a blackish-grey color;

when treated with water the filtrate should be colorless, or with the slightest green tinge; and should yield about twenty-four per cent. of available alkali.

A patent was obtained in 1853 by Elliot and Russell for an improved furnace, to be used in place of the usual black-ash furnace. This improvement consists in the substitution of a revolving cylinder of iron, lined with fire-bricks, for the chambers of the ordinary furnace, and with the later modifications by Messrs. Stevenson and Williamson, of the Jarrow Chemical Works, South Shields, Newcastle-on-Tyne. Its advantages appear to be of sufficient importance to induce its general adoption by soda manufacturers.

In the annexed drawing—Fig. 519—A is the cylinder made of malleable-iron plates, lined with fire-bricks, some portions of the lining being made to project in the form of shelves beyond the inner periphery of the brick cylinder, the shelves being intended to assist in mixing the charge. The malleable-iron cylinder is formed in two cast-iron rings, B B, which rest and run upon strong iron rollers, C C, supported in proper bearings. The cylinder is made to revolve slowly by means of a pair of pulleys and a train of wheels, as shown in the figure. The internal dimensions of the cylinder are—length thirteen feet, and diameter seven feet; D is the coal-burning furnace, from which flame escapes through a lateral orifice, corresponding with openings, E F, in the ends of the cylinder; and the flame, having traversed the chamber of the furnace, passes over the contents of a boiling-down pan, G, to the chimney.

Fig. 519.



When it is desired to charge the cylinder, the aperture, H, is raised to the position shown in the figure corresponding with a hopper containing the charge, and the charge is at once introduced. When the working of the charge is finished, the aperture, H, being unstopped, and the position of the cylinder reversed, it is run into a number of iron waggons, linked together, and brought consecutively under the aperture. With a cylinder of the above-stated dimensions the proper charge contains twenty-four hundredweights of sulphate of soda, with the usual proportions of chalk and small coal.

According to the invention of Stevenson and Williamson, as described in their specification, the chalk is first introduced into the cylinder with a portion of the coal, and heat is applied from the coal furnace. During this period, which continues about an hour and a half, it is only needful to cause the cylinder to revolve about once in five minutes, and the same rate of speed is sufficient until the decomposition of the charge approaches completion, when it is found necessary to increase the number of revolutions to the rate of one in two minutes. The effect of the previous heating of the chalk and coal is to convert the greater part of the chalk into caustic lime. When this is effected, the charge of sulphate of soda with the remaining portion of small coal is added; and the rotating motion, together with the application of heat, being continued during a further period of about an hour, the decomposition is completed, and the charge is ready for withdrawal. In this manner the furnace works off a charge every three hours, or decomposes nearly ten tons of sulphate of soda per diem, which is almost equal to the work of three ordinary black-ash furnaces.

The patentees state the advantages resulting from their improved furnace and mode of working to be—

1. The continual motion of the furnace causes its contents to become heated with perfect uniformity, so that no part of the charge ever attains an excessive temperature, and thus the loss of soda from volatilization is much diminished.

2. The mixing of the materials for the charge is effected without requiring the furnace to be opened for the introduction of implements, consequently without a current of air being drawn through the furnace during such mixing, thus providing for the atmosphere in the furnace being constantly devoid of free oxygen.

3. From the much larger quantity of work effected by the patent furnace at one time, a smaller number of skilled workmen is sufficient, and the risk of bad work is diminished, and a more complete decomposition of the sulphate of soda is insured by the more perfect mixing.

4. The waste of soda by absorption into the beds of the ordinary furnaces is avoided, and no tools being used in the process of mixing, the surface of the brick lining is less subject to injury from working than the bottoms of reverberatory furnaces.

Theory of the Decomposition.—The conversion of the sulphate into carbonate of soda by the above-described method of LEBLANC is a very complicated process of decomposition. Some French chemists, however, amongst whom DUMAS may be mentioned as the foremost, take a very simple view of the case. They suppose that when sulphate of soda, carbonate of lime, and charcoal are fused together in the proportions given above, in the first place the sulphate of soda and carbonate of lime react upon each other, producing carbonate of soda and sulphate of lime thus:—

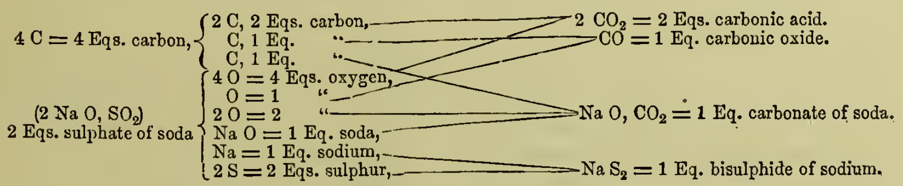
$$\underbrace{Na\,O,\,SO_3}_{\text{Sulphate of soda.}} + \underbrace{Ca\,O,\,CO_2}_{\text{Carbonate of lime.}} = \underbrace{Na\,O,\,CO_2}_{\text{Carbonate of soda.}} + \underbrace{Ca\,O,\,SO_3}_{\text{Sulphate of lime.}}$$

The sulphate of lime, in contact with incandescent charcoal, yields its oxygen to the latter element, and carbonic oxide, or a mixture of this and carbonic acid is evolved, leaving protosulphide of calcium in admixture with the carbonate of soda previously produced.

Other chemists take a different view of the decomposition. According to GMELIN, the sulphate of soda is reduced by the charcoal to the state of sulphide of sodium, with evolution of carbonic oxide gas; and the sulphide of sodium so produced is converted by the carbonate of lime into sulphide of calcium and carbonate of soda; and when three equivalents of carbonate of lime are used to two of sulphate of soda, the result is shown in the annexed equation:—

$$\underbrace{3\,(Ca\,O,\,Co_2)}_{\text{Carbonate of lime.}} + \underbrace{2\,(Na\,O,\,SO_3)}_{\text{Sulphate of soda.}} + \underbrace{9\,C}_{\text{Charcoal}} = \underbrace{(Ca\,O + 2\,Ca\,S)}_{\text{Oxysulphide of calcium.}} + \underbrace{2\,(Na\,O,\,Co_2)}_{\text{Carbonate of soda.}} \quad \underbrace{10\,CO}_{\text{Carbonic oxide.}}$$

In the statement of the result of the decomposition, DUMAS and GMELIN agree precisely; they differ, however, as to the mode by which the result is obtained. LIEBIG shows the action of charcoal upon sulphate of soda to be far more complex than as stated by GMELIN, and gives the following diagram in elucidation of his views:—



If carbon is present in greater proportion, it is taken up by the carbonic acid gas, which thereby passes into the state of carbonic oxide—

$$\underbrace{CO_2 + C}_{\text{Carbonic acid.}\quad\text{Charcoal.}} = \underbrace{2\,CO}_{\text{Carbonic oxide.}}$$

Supposing this to be a true statement of the transformations, the subsequent decomposition—namely, the reaction of carbonate of lime upon bisulphide of sodium—must also be far more complicated than is usually supposed. It is exceedingly difficult to arrive at any positive conclusion from the views of different chemists upon this subject. It is certain, however, that the calcination of sulphate of soda with both coal and carbonate of lime at the same time, is by no means essential to the process; if desirable, the sulphate might first be treated with coal alone, and the resulting sulphide or mixture of sulphide and carbonate be afterwards calcined with carbonate of lime.

Composition of Black Ash.—Probably in no other department of chemistry does a greater difference of opinion exist among theorists, than as to the true composition of black ash. The principal, but by no means the sole discrepancy in their statements, is found in their different views of the composition of the insoluble lime salt. When a mixture of sulphide of calcium and carbonate of soda in *equivalent proportions* is treated with water, insoluble carbonate of lime is formed, and sulphide of sodium is obtained in solution. But if to the mixture of carbonate of soda and sulphide of calcium a portion of lime be added, and the compound be then affused with water, the soda salt, partially deprived of its carbonic acid, alone dissolves, and the sulphide of calcium remains unaltered.

The question to be solved, therefore, is—in what manner does the free lime prevent the decomposition that would otherwise ensue? Many chemists explain the difficulty, by supposing that the lime—Ca O—enters into combination with the sulphide of calcium. In the first place, however, it must be borne in mind that this supposed compound has never yet been isolated, so that its precise composition cannot, therefore, be ascertained.

DUMAS, and some others assume it to be a combination of two equivalents of sulphide of calcium with one equivalent of lime—$2\,Ca\,S + Ca\,O$. UNGER, reviewing DUMAS' theory of the process of its formation, considers it much more probable that it is a compound of three equivalents of sulphide of calcium with one equivalent of lime—$3\,Ca\,S + Ca\,O$—a formula also assigned to it by PAYEN, and adopted by many others. ROSÉ regards it as composed of one equivalent of sulphide of calcium, with one of hydrate of lime—$Ca\,S + Ca\,O,\,HO$.

The conclusion that combination of sulphide of calcium with lime does ensue, appears to have been arrived at, not from an analysis of the pure compound, for, as mentioned above, it has never yet been obtained, but simply because, in the presence of free lime, the sulphide of calcium *does not dissolve* when treated with water. This is indeed the only argument stated by DUMAS to account for the existence of his $2\,Ca\,S + Ca\,O$; and certainly the fact that an additional proportion of lime in the preparation of black ash does render the sulphide of calcium more insoluble, seems a powerful argument for the existence of this or a similar compound. Unger, however, reasoning analogically, argues that because Rosé obtained a salt having the formula $3\ Ba\,S,\ Ba\,O,\ 28\ HO$, the compound—$3\ Ca\,S,\ Ca\,O$—though free from water, might also be supposed to exist. This, although affording a strong presumption, cannot be accepted as a conclusive proof; and still the question remains—If sulphide of calcium is more soluble in the presence of free lime than in the pure state, why is this the case? In an investigation into the composition of black ash performed a few months ago by Mr. J. W. Kynaston in the Editor's laboratory, it was found that when the ash was treated with water, and allowed to remain for some time undisturbed, the lime previously existing in the ash in the free state, by acting upon the solution of carbonate of soda, eliminated caustic soda, *itself becoming wholly converted into carbonate.* This, if not conclusive proof of the non-existence of the hitherto assumed compounds of sulphide of calcium and lime, at least shows that the stability of the sulphide of calcium of black ash, when treated with water, is not to be ascribed to the production of any such compound. In this view Mr. Kynaston is supported by the observations of Gossage, than whom probably no one ever performed so numerous a series of experiments upon black ash, and more especially upon its insoluble portion. Mr. Gossage states that he has long held this view, and, indeed, founded upon it a process for the recovery of the sulphur from the insoluble portion of the ash, to which further reference will shortly be made. Mr. Kynaston suggests that, instead of the combination of sulphide of calcium with lime, a compound may exist of sulphide of calcium with carbonate of lime, and having the formula $2\ Ca\,S,\ Ca\,O,\ C\,O_2$. Were further evidence required, an additional proof that the whole, or at least the greater part, of the free lime of black ash is converted into carbonate, when the ash is treated with water, is the fact of the existence of so large a proportion of caustic soda in black-ash liquor, and the presence of which cannot be satisfactorily explained in any other way. Some chemists—indeed by far the greater number who have written upon the subject—do give hydrate of soda as a constituent of black ash. It will not, however, be difficult to show the fallacy of this. Knapp accounts for the proportion of caustic acid, by supposing a portion of the carbonate of lime to be burnt and converted into the caustic state, before the decomposition of the soda salt is effected; the caustic lime, then acting upon the sulphide of sodium, produces sulphide of calcium and caustic soda:—

$$\underbrace{Ca\,O}_{\text{Lime.}} + \underbrace{Na\,S}_{\text{Sulphide of sodium.}} = \underbrace{Ca\,S}_{\text{Sulphide of lime.}} + \underbrace{Na\,O}_{\text{Soda.}}$$

One may be permitted to doubt whether this reaction would take place under the circumstances. Carbonate of soda, treated in solution with caustic lime, gives rise to the formation of caustic soda and the insoluble carbonate of lime. But if caustic soda and carbonate of lime be fused together, carbonate of soda and caustic lime are produced. So if a mixture of caustic soda and sulphide of calcium be fused together, sulphide of sodium and caustic lime are formed, $Na\,O,\ Ca\,S,\ = Na\,S,\ Ca\,O$; but if the resulting mass be treated with water, caustic soda and sulphide of calcium are reproduced. It cannot be reasonably supposed, that when in the case of the pure salts the above-mentioned reaction is well known to take place, in the production of black ash, exactly the reverse action should ensue with the same salts and by a similar mode of treatment. Yet it is well known that in the preparation of black ash, caustic lime may be, and in the early days of the manufacture in this country was, used instead of carbonate of lime. But in such a case a predisposing cause, if the term may be allowed, determines the reaction. When zinc and water are placed in contact, the water is not decomposed; but if an acid be added, decomposition of the water rapidly takes place. So when sulphate of sodium and lime are fused together no change occurs; but when charcoal is also present, and hot air is blown upon the mass as in the reverberatory black-ash furnace, decomposition immediately follows.

Carbonic acid is here the *predisposing cause*, just as sulphuric acid is in the case of zinc and water. The success of this soda process is, indeed, in no small degree owing to the remarkable affinity of soda in the fused state for carbonic acid; and this is so great, that even supposing caustic soda to exist in the black ash at any time during its preparation, it could not remain more than a few moments uncombined in the atmosphere so highly charged with that acid. It is further to be noticed that all those analysts who state hydrate of soda to be a constituent of black ash, also include *carbonate of lime* amongst the ingredients. But what an inconsistency to suppose that hydrate of soda and carbonate of lime can exist, after fusion together for such a length of time as in the preparation of black ash, when the two salts so readily decompose at a much lower temperature than that to which the mass is subjected. Still another argument against the existence of caustic soda in black ash presents itself, if the theory of Dumas and others of the French school be accepted as the true one. These explain the reaction, by supposing that the sulphate of soda and carbonate of lime first decompose the bases, exchanging acids, and that the sulphate of lime so formed is afterwards reduced to sulphide of calcium by the charcoal. In this case *no caustic soda can have been formed;* and as carbonic acid once combined with soda cannot be again removed by simple heating, of course no caustic soda can be produced. In conclusion, the Editor must again assert, that as yet no sufficiently satisfactory proof has been put forward to show *hydrate of soda to be a constituent of black ash;* while, on the other hand, its existence in the black-ash liquors is quite consistent with the views expressed above. But if this be admitted, the theory that the sulphide of calcium owes its insolubility and permanence to its having entered into combination with free lime, is of course disproved. The fact does not indeed require such a far-fetched explanation. Protosulphide of calcium is itself *very insoluble*, bisulphide of calcium is *readily soluble*, and all that it appears necessary to guard against is the formation of bisulphide of calcium, or rather perhaps of bihydrosulphate of lime, which is so liable to be produced.

Whether a sulphite and hyposulphite actually exist in black ash, is a question that hardly admits of proof. They are included in the analyses of several investigators, and the researches of Mr. KYNASTON certainly lead to the same conclusion. Still the probability of the formation of these, subsequent to the removal of the black ash from the furnace, *is so obvious, that until the point has been conclusively determined, it is better not to express any positive opinion.* Black-ash liquors certainly contain both salts. Sulphate of soda and ferrocyanide of sodium are frequently constituents of black ash, but these are not always present. The Editor has had numerous samples examined which were free from even a trace of either one or the other. The subjoined analyses of this highly complex mixture are by UNGER and RICHARDSON. Both, it will be seen, *assume* the existence of a compound of sulphide of calcium and lime, and also of caustic soda.

	From Newcastle. Unger.	From Newcastle. Richardson.
Sulphate of soda,	1·99	3·64
Chloride of sodium,	2·54	0·60
Carbonate of soda,	23·57	9·89
Hydrate of soda,	11·12	25·64
Carbonate of lime,	12·90	15·57
Oxysulphide of calcium ($3\,CaS + CaO$),	34·76	35·57
Sulphide of iron,	2·45	1·22
Silicate of magnesia,	4·74	0·88
Charcoal,	1·59	4·28
Sand,	2·02	0·44
Water,	2·10	2·17
Loss,	0·22	—
	100·00	100·00

Mr. KYNASTON'S analysis is also appended :—

Carbonate of soda,	36·879
Chloride of sodium,	2·528
Sulphate of soda,	0·395
Silicate of soda,	1·182
Aluminate of soda,	0·689
Sulphide of calcium,	28·681
Carbonate of lime,	3·315
Bisulphide of calcium,	0·435
Hyposulphite of lime,	1·152
Sulphite of lime,	2·178
Caustic lime,	9·270
Magnesia,	0·254
Sulphide of iron,	0·371
Sesquioxide of iron and phosphate of lime,	2·658
Alumina,	1·132
Charcoal,	7·007
Sand,	0·901
Ultramarine,	0·959
Water, hygroscopic,	0·219
	100·205

Annexed is another analysis of black ash, just made by Mr. MARTIN MURPHY, the Editor's talented assistant, and whose aid in scientific and literary matters for twelve years he has found of the utmost service :—

Soda,	25·388
Lime, chiefly existing as sulphide,	35·484
Carbonic acid,	17·599
Sulphur,	14·747
Sulphuric acid,	0·421
Iron,	3·020
Alumina,	1·165
Silicic acid,	0·945
Chlorine,	0·794
Charcoal,	5·724
Ultramarine and sand,	1·659

The preceding numbers correspond with the following order of combination :—

Carbonate of soda,	41·489
Sulphate of soda,	0·748
Chloride of sodium,	1·308
Aluminate of soda,	0·392
Silicate of soda,	1·162
Sulphide of calcium,	33·193
Caustic lime,	9·320
Carbonate of lime,	0·857
Sesquioxide of iron,	3·020
Alumina,	1·020
Charcoal,	4·724
Sand, *et cetera*,	2·259
	100·000

The characteristics of good black ash are as follows: —It should be of a blackish-grey color, and with open pores, similar to pumice-stone, so that a liquid may easily penetrate its substance. It should contain from twenty to twenty-four per cent. of available soda, and should be free, or contain only a slight trace of sulphate of soda. When the solution obtained by lixiviating a portion is acidified, merely a faint smell of sulphide of hydrogen should be perceptible.

Lixiviation of the Black Ash.—This is the next operation in the process of manufacture, and is the first step towards the preparation of pure soda from black ash. Its object is the separation of the soluble constituents from the calcareous and other insoluble matters present. To effect this the balls of crude soda, a day or two after preparation, are broken to fragments and thrown into iron vats. By some it is recommended, first, to crush or grind the ash under upright millstones, and afterwards to sift it, or else to crumble it by exposure to hot vapor. With this view, the ash is sprinkled with water in a tolerably hot furnace, where, in the atmosphere of vapor, it soon swells up and falls to pieces. If the ash has been properly prepared this proceeding is quite unnecessary, and indeed objectionable on other grounds than the expense and labor required. With ash that has been allowed to remain too long in the furnace it may, however, be necessary to heat it in such a manner, otherwise the extraction of the soluble ingredient occupies too long a period of time; and it must be borne in mind that the longer the liquor is allowed to remain in contact with the insoluble portion of the ash, or the *soda water*, the greater the amount of sulphide of sodium in the solution, and this must be subsequently got rid of, or the ash will be unfit for use.

The vats used in the process of lixiviation are of iron, and of considerable size, and are so arranged as to allow the separation of the soluble constituents of the ash with the smallest possible proportion of water.

But although, as KNAPP observes, it is desirable, on the one hand, to use as little water as possible, yet it is equally necessary on the other hand to dissolve out *every particle of alkali from the residue.* In this, as in all other similar cases, both objects have been obtained by one and the same ingenious method.

The difficulty is obvious; if too little water be used in the first instance, a portion will remain undissolved. In the contrary case all the alkali will be dissolved, but, as at first, the whole solution cannot be drawn off; for a considerable quantity is kept back by the spongy residue. It is, therefore, impossible in any case to obtain the whole quantity of soluble matter with one portion of water; a second, third, and fourth portion will be required, each of which will contain a less quantity in solution, so that, altogether, there will be a vast excess of liquid. The contrivance by which this difficulty is overcome, depends upon an uninterrupted continuance of the process, and consists in using the same water which was employed for the first infusion, with fresh portions of crude ash, until the solution has acquired the proper strength for boiling.

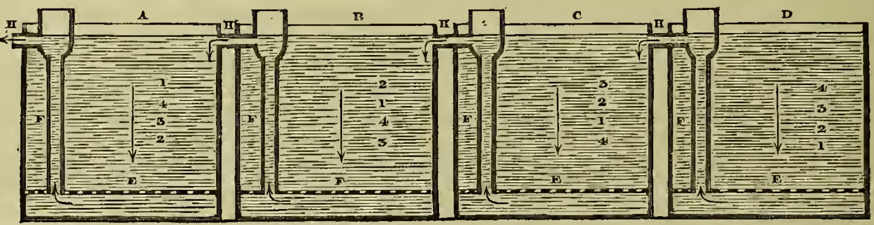
Just in the same manner every second or subsequent infusion can be increased in strength, so that none but sufficiently concentrated lie is supplied to the evaporating pan. Suppose that a certain quantity of water has taken up eight per cent. from the first portion of the soda, it will take up as much more from the second, and leave it containing sixteen per cent.; from the third portion it will be drawn off with twenty-four per cent., and so on.

The lixiviation was formerly effected in vats so placed at different elevations, that weak liquors resulting from partly lixiviated ash flowed upon ash contained in a fresh set vat; but in using such apparatus, the manufacturer had to remove the partially lixiviated ash into higher vats, and yet the strongest liquors obtained rarely exceeded a specific gravity of 1150°, and consequently a very large quantity of water had to be evaporated to obtain dry salt. A very ingenious and scientific apparatus was invented and applied successfully by the celebrated French chemist, CLEMENT DESORMES. This apparatus provided for obtaining solutions of much higher gravity, but necessitated the employment of much manual labor, and also occupied a large space. The lixiviating apparatus which is now universally adopted by the manufacturers of soda in this country, the Editor knows to be a foreign invention, which was introduced by Mr. C. T. DUNLOP into the St. Rollox Chemical Works, Glasgow, about the year 1843. This apparatus from its extreme simplicity, correct scientific principles, and the perfect manner in which the lixiviation is effected by its use, appears to fulfil all the conditions which can be desired in this process.

The apparatus is represented in Fig. 520, and may be described as consisting of a rectangular vessel about twenty-four feet long by twelve feet wide, and five deep, having three partitions, H H, dividing it into four vats, A, B, C, D, of twelve feet by six feet. Perforated false bottoms, E E, are supported about three inches above the bottom of the vats, on which the black ash is thrown in lumps. Each vat is furnished with a vertical pipe, F, five feet long, the lower end of which is open, and communicates with the space below the false bottom. About one foot six inches from the upper end of this pipe a short branch is provided, and this branch is bolted to the side plate of the vat; an opening being made in the side plate, to correspond with that in the branch. By these means a communication is effected between the lower part of one vat, and the upper portion of another. The upper part of the pipe, F, is enlarged; and at the lower part of this portion, a conical seating is provided, which admits of the passage being closed by a plug, or of a short pump being applied to withdraw the fluid contents of the vat.

When in regular use, the four vats will contain black ash at various stages of lixiviation, diffused in their corresponding liquors—one being filled with fresh balls; and another, furthest distant from it in the series, containing residuum all but deprived of its soluble matter. A supply of warm water is run upon the first and nearly spent vat; and this, after permeating through the residuum and becoming impregnated with alkali, rises through the pipe F, and flows into the upper part of the second vat, through the contents of which it passes, taking up more alkali, and rising again by a similar pipe, gains access to the third vat, and so on into the fourth vat, in which the liquor becomes fully saturated by its contact with the fresh balls. The flow of liquor from the last vat may be intermittent, but it is preferable that it should be continuous; the supply of warm water to the first vat being also continuous, and this vat kept constantly filled. When it is found that the liquor proceeding from the first vat contains scarcely any alkali, this vat is shut off from the series; and the remaining liquor being pumped out, the residuum is removed, and the vat filled with fresh balls. This vat now becomes the fourth of the series, and receives liquor from that which was previously the fourth, by means of a pipe leading externally from the lower part of the latter to its upper part. When the vats are arranged in a square of four as shown in Fig. 521, in place of four longitudinally, this external pipe is not needed. In this manner each of the vats becomes consecutively the one to be discharged, and to be refilled with fresh balls.

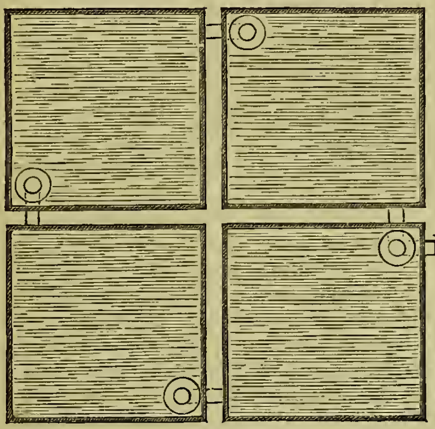
Fig. 520.



In large establishments, a series of sixteen or more vats in a double row are employed, and these may be constructed by fixing longitudinal and transverse partitions in one large vessel.

By the provisions of this highly scientific apparatus, it becomes no longer needful to remove the black ash during the process of lixiviation; which removal was previously attended with much labor, injurious exposure to the oxidising influence of the air, and great diminution of the permeability of the mass. The residuum in the above admirable arrangement, is constantly supported by the fluid in which it is immersed, and thus kept in a condition highly favorable to its permeability; and the solvent is caused to percolate through the contents of the whole series without the cost of pumping. Practically, the advantages have been found to comprise a much more perfect abstraction of the soluble parts of black ash, and the obtaining of solutions requiring less than half the evaporation formerly necessary; indeed, so perfect is the process of lixiviation, that scarce one-tenth per cent. of soda is left in the residue.

Fig. 521.



In some alkali works, to assist the solvent power of the water employed in the lixiviation of black ash, it is usual to heat it to about 90° to 100°. This end may be conveniently attained by passing the water through a coil of pipes contained in a steam boiler. The practice of heating the water, though it undoubtedly aids the process of lixiviation, is nevertheless very objectionable, principally because sulphide of calcium is dissolved and decomposed by hot water, giving rise to the formation of sulphide of sodium, and the hotter the water the greater will this proportion of sulphide be, or rather of the double sulphide of sodium and iron contained in the vat liquor.

The temperature of the water, it must also be observed, always rises considerably—20° to 30° or more—on coming in contact with the fresh black ash in the fresh vat, owing to the powerful affinity of caustic lime for that liquid to produce hydrate of lime. In summer the liquor frequently becomes so hot as to render necessary its withdrawal considerably below the point of saturation, otherwise the ash obtained on evaporation would be so strongly impregnated with sulphide, that it would be quite inapplicable to many purposes.

If the temperature of the liquor should not rise higher than from 110° to 120°, it may remain in contact with the ash until of specific gravity 1·225 = 45° Twaddell; in the contrary case it should be withdrawn at a density of 1·200 = 40° Twaddell, or even still lower. Water is allowed to run into the weak vat until the density of the liquor passing through is reduced to 1·10 to 1·15 = 2° to 3° Twaddell, and the insoluble matters remaining should, after being dried, contain not more than 0·2 or 0·3 of available soda. This last portion, if extracted, would contain so large a proportion of sulphate and other salts of lime, that on coming into contact with the ash in the next vat, it would decompose and render valueless more than an equivalent proportion of soda.

The composition of vat refuse—soda waste—according to Unger's analysis is as follows:—

Carbonate of lime,	19·56
Oxysulphide of calcium, $3\,\mathrm{Ca\,S} + \mathrm{Ca\,O}$,	32·80
Sulphate of lime,	3·69
Hydrosulphite of lime,	4·12
Hydrate of lime,	10·69
Bisulphide of calcium,	4·67
Sulphide of calcium,	3·25
Sulphide of sodium,	1·78
Oxide of iron,	3·70
Silicate of manganese,	6·91
Charcoal,	2·60
Sand,	3·09
Water,	3·45
	100·31

The sample of waste examined by Unger must have been some time exposed to the air. When fresh it contains, according to the Editor's observations, *no bisulphide of calcium*, and but little hydrate of lime either free or in combination. The sulphate of lime also is wholly formed, subsequent to the removal of the soluble constituents of the ash. After being kept for some time only partially dried, a large quantity of sulphite and hyposulphite of lime is also produced, and the mass becomes of a dirty white color, with streaks of a beautiful blue color, running through it. The liquor containing in solution the salts of soda removed from the black ash, as it is withdrawn from the vats, is conducted into a series of settlers or iron vats. In these it is allowed to rest for some hours, to deposit any impurities that may be held in suspension. It is then pumped into a spacious cistern or reservoir, so elevated that, by means of pipes, the liquors may be distributed to the concentrating pans and furnaces.

Evaporation of the Lie.—The process of concentration is carried on in two different ways. Most commonly the solutions are evaporated and the residue calcined in the same reverberatory furnace, known as the *white-ash furnace*, whose extreme length should be about eighteen feet, and the breadth about nine feet. Its interior is lined with fire bricks, between which and the external masonry is placed a partition of sheet iron. By the application of heat in this manner, the evaporation proceeds rapidly, quietly, and at a very moderate expense of fuel. The waste heat from the black-ash furnaces is frequently applied to the evaporation of vat liquors. In this case, an iron pan termed the *salting pan*, in shape similar to the furnace above described, is placed at the end of the black-ash furnace next to the raised bed. The evaporation proceeds rapidly as with the ordinary white-ash furnace; but the mass of ash is not allowed to become completely dry. As soon as the contents of the pan have attained the consistence of mortar, they are raked out into a large iron called the *drainer*, furnished with a false perforated bottom, to allow the mother liquor to drain from the crystals. The drained mass is next collected and introduced into a reverberatory furnace, named the *finishing furnace*, in which it is moderately calcined, and at the same time dexterously worked about in all directions so as to bring every part of it in contact with the air, and within the action of the flame. The mother liquor or draining from the *salts*, which contains nearly all the caustic soda and sulphide of sodium and iron, as well as the excess of foreign salts, sulphate of soda and chloride of sodium, *et cetera*, is in some works returned to the salting pans with the next charge of fresh liquor; in others it is evaporated *per se*, and the residue is afterwards heated to redness, mixed with saw-dust or coal-dust in reverberatory furnaces. During the process of calcination the sulphur of the sulphide of sodium escapes in some form of combination, and carbonate of soda is produced; the caustic soda also quickly combines with carbonic acid to produce the same salt, and the sulphate of soda is reduced at the same time to sulphide of sodium, and undergoes a similar change.

In manufactories where caustic soda is produced in a marketable form, it is principally extracted from the mother liquors above-mentioned.

The other method of conducting the evaporation of vat liquors is by means of iron pans, with the fire and heated air applied beneath. These—named *fishing pans*—are of considerable size, and shaped somewhat similar to a boat. They may be heated by a fire used solely for the purpose; in which case to prevent injury to the pan, the arch of the furnace should be continued for some distance beneath, or the pan may be placed at the end of the black-ash furnace farthest from the fire, just as with the salting pan, except that the heated air is made to pass under instead of over the pan. The evaporation is rapidly conducted by this method; and when the lie becomes concentrated to a certain strength, small crystals of monohydrated carbonate of soda—NaO, CO_2, HO—constantly fall to the bottom, and as quickly as they fall are raked together to the end of the pan farthest from the source of heat, and then scooped or *fished* out by means of perforated iron shovels. After being allowed some time to drain, the salts so obtained are washed with fresh vat liquor, and then removed a reverberatory furnace, and all worked about until sufficiently dry. The deep-red mother liquor is either applied to the production of caustic soda or evaporated, and the residue heated with sawdust as before directed.

In some alkali works the evaporation of black-ash liquors is conducted in a series of pans, three or four in number, or rather in one pan separated into three or four compartments; in the first, that is, the one at the greatest distance from the source of heat, the solutions are heated to the point of ebullition; in the next, or the two next, the liquors are concentrated until saturated while hot; and in that immediately in contact with the fire, the concentrated liquors are evaporated either to dryness, or until nearly the whole of the carbonate of soda is deposited from solution, and this is afterwards dried in a reverberatory furnace as before.

In the year 1853 an improved mode of concentrating black-ash liquors for the purpose of obtaining salts therefrom suitable for the manufacture of soda ash, was invented by Mr. GOSSAGE, and secured by patent. The following description of the method is in the words of the patentee, and is extracted from the specification:—A long iron pan is provided and heated, either by means of a special fire underneath the same, or by waste heat proceeding from the alkali furnaces. A second long pan is placed contiguous to the first, but to this no heat is to be applied; a channel of communication is provided, and having introduced a suitable quantity of black-ash liquor into both pans, heat is applied to the first pan, so as to produce concentration of the liquor. A continued circulation of the solution through the two pans is effected by pumping or otherwise transferring liquor from the second into the first pan, at the end opposite to that at which the channel of communication exists. By this arrangement the liquors become so concentrated in the first pan as to contain more salts when in a heated state than they can retain in solution at a lower temperature, and therefore as the liquors flowing through the second pan become reduced in temperature, salts are deposited in this pan, and the liquors circulate again through the first pan as required, so as to keep a suitable quantity in the apparatus.

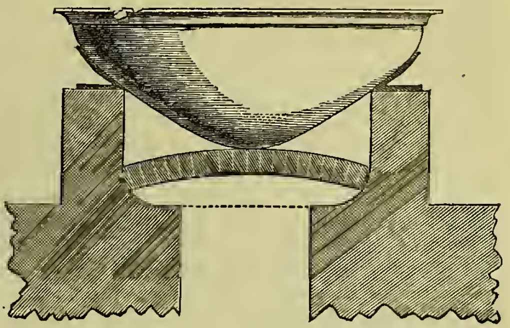
In the process of concentration by the ordinary method in a single pan, the salts, as they are deposited from the solution, collect at the bottom, and form a compact mass of a greater or less thickness, and the heat being continued owing to the bad conducting power of the deposited salts, the part of the pan immediately over the fire, if constant attention is not exerted, frequently becomes heated almost to redness; and if by any means the colder liquid comes in contact with this at so high a temperature, not only is the solution violently thrown from the pan, occasioning considerable loss of liquor, but often the latter becomes cracked, and, of course, is rendered useless until repaired. The advantages of Mr. GOSSAGE's apparatus will therefore be at once apparent, since by his mode of arrangement none, or at least only a small deposition of salts, can take place in the pan to which heat is applied. The patent to which reference has just been made, also includes an improved mode of concentrating black-ash liquors, when it is desired to obtain therefrom in a remarkable state the caustic soda they contain. The apparatus employed consists of an oblong vertical tower, made of iron plates, to the inside of which tower is adapted a number of iron shelves, placed at such an inclination that fluid will flow freely down the same. One of these shelves is attached to one end and to both sides of the tower, leaving a space of about three inches in width between it and the other end. The next shelf is attached a few inches below the first to the opposite end and to the two sides of the tower, leaving the same space between it and the other end. In this manner each alternate shelf is attached to an opposite end of the tower, and the arrangement is such that a supply of fluid introduced on the upper part of the first inclined shelf flows down the same, and is delivered on the upper part of the second shelf, and after flowing over this reaches a third, and so on consecutively over the whole number of shelves contained in the tower. By these means the fluid employed may be exposed, in thin sheets or films, to the evaporated action of heated air passing through the tower. A supply of heated air is provided by any of the ordinary methods, and the apparatus is connected with the previously mentioned tower, at or near its lower part; and to occasion a large quantity of heated air to pass through, the upper part of the tower is connected with a strong chimney draft. The liquid to be evaporated is introduced into the tower in such a manner that it becomes distributed nearly equally over the uppermost shelf, from which it flows in the same manner over the succeeding shelves, and, exposed to the evaporating action of highly heated air during its course, becomes so heated and concentrated as to contain more salts than it can retain in solution at a lower temperature. A channel of communication from the lower part of the tower is provided, through which the hot concentrated fluid is conveyed to two iron pans; in flowing through these it becomes cooled so as to deposit salts, and the remaining fluid is then elevated by means of a pump from the coolest part of the pans and caused to pass again through the tower.

The inventor prefers to apply this mode of concentration for obtaining soda from vat liquors, to such liquors as have been already deprived of a considerable portion of the carbonate of soda previously contained therein. The circulation of these liquors through the tower is continued until it is found that the whole, or nearly the whole, of the carbonate of soda is removed, when the liquor is separated from the deposited salts, and by further evaporation in an iron pan solid hydrate of soda is obtained. The separated salts, after being washed, are transferred to a reverberatory furnace and completely dried. The product of these operations, whichever of the foregoing be adopted, is the *white ash* or *soda ash* of commerce. When properly prepared it contains fifty-three or fifty-four per cent. of available soda, two or three of which exist in the form of hydrate, and the rest as carbonate of soda. A little sulphide of sodium is also present, and some sulphate of soda, chloride of sodium, and minute quantities of other salts.

A new arrangement or apparatus for effecting the evaporation of black-ash liquors has been invented and successfully applied by Mr. D. GAMBLE, at St. Helens, Lancashire. It has been adopted very generally by the Lancashire manufacturers, particularly by those who are makers of solid caustic soda from black-ash liquors by GOSSAGE'S process. Mr. GAMBLE employs a pan of malleable iron, of the form indicated in Fig. 522, having a length of thirty feet, a width of seven feet, and greatest depth two and a half feet. The pan is placed above, or at the end of a black-ash furnace, and is heated by conducting the waste heat of the furnace by flues under the sides of the pan. The form of these sides is such as to afford facilities for separating the salts from the sides of the pan, when these adhere. During the boiling down, the salts are transferred in ladles into perforated drainers.

Mr. GAMBLE was also the first to use centrifugal machines, or hydro-extractors, for separating mother liquors from salts obtained from black-ash liquors, and by such an apparatus soda ash of fine quality has been obtained, by the first process, without being redissolved and evaporated.

Fig. 522.



The analyses of soda ash appended were performed by Mr. KYNASTON in the Editor's laboratory. The ash was obtained by evaporating the liquors at once to dryness, and calcining the residue.

	Centesimally represented.	
Carbonate of soda	67·891	73·626
Hydrate of soda	14·245	13·600
Sulphate of soda	4·579	6·127
Chloride of sodium	6·061	4·431
Sulphide of sodium	0·556	0·361
Aluminate of soda	1·214	..
Silicate of soda	0·389	0·511
Insoluble matters	0·217	1·579
Water	5·005	
Ultramarine	0·140	..
	100·297	100·235
Available soda	50·75	54·00

The soda ash prepared by the processes described is, without further treatment, sufficiently pure for almost all the ordinary manufacturing applications of soda. For some purposes, however, and especially for the fabrication of plate glass, or for the production of the crystallized carbonate of soda—soda crystals—the ash made as above requires to be still further purified; and this is most commonly effected by giving it another calcination in a reverberatory furnace, moderately heated, sometimes by a charcoal fire. Or the salts obtained by evaporation of the vat liquors, either in the reverberatory furnace, or in the *fishing pans*, after being thoroughly drained and washed as completely as possible from adhering impurities, either with fresh liquor or with water, are mixed with saw-dust or coal dust, and calcined in a reverberatory furnace.

This calcination is intended to effect the separation of the sulphur from the small proportion of sulphide of sodium still remaining in the ash, and also the combination of all the particles of caustic soda in the ash, with carbonic acid derived from the burning carbonaceous matters introduced.

The heat applied in the first part of this process should not greatly exceed the melting point of lead.

At that temperature the sulphur goes off freely; but at a dull red heat the sulphur, instead of being volatilized, seems to enter into more permanent combination with the alkali.

The ash requires to be worked about with the oar and rake during the whole course of the operation, which usually takes about three or four hours. After the sulphur is expelled as completely as possible, the fire should be gradually urged until the mass attains a dull red heat, and this is continued until every particle of carbon is removed. The product of this operation is usually of a slightly yellowish or bluish-white tinge, and is excellent material for the manufacture of plate glass. The available soda exists wholly in the state of carbonate, and if any, only the most minute trace of sulphide of sodium. It must not be supposed, however, that this result is arrived at without the most careful manipulation, and constant attention to keep the furnace at the proper temperature required in the several stages of the operation. Ash so prepared should not, on exposure to the air for some time, undergo any alteration in hue, and when dissolved in water should yield a perfectly colorless solution. If it answers to these tests, the plate glass manufacturer may rest assured of its applicability to his purpose.

This ash being wholly in the state of carbonate, the amount of available soda contained in it is not quite so great as in some other varieties.

CRYSTALLIZED CARBONATE OF SODA—*Soda Crystals.*—This salt is prepared by dissolving soda ash, obtained as above, in hot water to the point of saturation, and the solution after reposing for some time is run into shallow pans of cast-iron or of wood, lined with sheet-lead, and allowed to remain at rest until the crystallization is completed. That the operation may be successful in a pecuniary point of view, it is essential that the salt be obtained perfectly colorless by a single crystallization. It is, therefore, necessary to observe particular care in the several operations, and especially in the selection of the ash to be dissolved. Nor is it by any means unimportant *that the water used should be as free as possible from carbonate of iron and the salts of the alkaline earths.* The ash most suitable is that prepared by the method last described. The alkali contained in it must exist wholly as carbonate. Sulphide of sodium must not be present, even in the smallest proportion; it should be as free as possible from carbonate of lime, and on exposure to the air should not undergo the slightest alteration in color. The solution is effected in different ways by different manufacturers. In the mode now most commonly employed, the lie is heated by means of steam blown into it. The dissolving pan, which is of iron, should be of such a size that sufficient ash may be treated at one operation to yield two, three, or four tons of crystals. Water being run in to about two-thirds full, it is heated to nearly ebullition, and ash is then thrown in, the injection of steam being continued until the solution has a specific gravity of 1·225 = 45° Twaddell. It is then siphoned into a capacious iron vessel termed the settler, where it is allowed to remain twelve or fourteen hours to deposit any insoluble matters that may be present. The clarified liquor is now conducted to a boiler placed over an open fire, where it is heated and kept in a state of ebullition until the density becomes about 1·275 = 55° Twaddell. At this point it is again run off to the settlers, a pailful of solution of bleaching powder, or of chalk and water, or a mixture of these, is thrown in to aid the deposition of the impurities, and the whole is allowed to remain until the temperature is reduced to about 92°. At a little lower degree of heat crystals begin to be formed; but before this can take place the liquor is conveyed by means of sluices to the crystallizing pans or *cones*, which are of such a size as to contain sufficient liquor to give from a ton to a ton and a half of the crystallized salt. The annexed engraving shows the manner in which they are arranged in the crystallizing house.

To determine the formation of a larger quantity of very pure crystals, iron rods or bars are laid across the cones, and the crust that forms at the surface of the liquid, adhering to these, is prevented from falling, and will sustain also the mass of crystals that grow immediately beneath it. After nine or ten days—the length of time varying with the season—the crystallization may be considered complete. The mother liquor is then siphoned off, and by evaporation and calcination of the residue, a very white ash is obtained, containing about sixty-five per cent. of carbonate of soda, the other thirty-five being principally sulphate of soda and chloride of sodium. The crystals are allowed to remain a short time in the cones after the removal of the mother liquor, so as to drain and become dry, and are then taken out to be packed.

In some alkali works the soda ash, instead of being treated as above, is dissolved at once by the aid of steam, until the solution has attained a density of 1·275 = 55° Twaddell. It is then drawn off to the settlers, a quantity of bleaching powder or chalk added, and when the temperature is near 92°, conveyed to the cones. From some varieties of ash, however, the impurities are not so readily separated, and it is necessary to substitute the process above given. The slimy deposit from the settlers with the adhering liquors, is either returned to the dissolving pan, or when collected in quantity is mixed with fresh water, boiled by means of steam; and the solution, after depositing the gross impurities, is added to the mother liquor from the crystals, and evaporated with it to dryness.

Though the process for the manufacture of soda ash, as detailed above, is very complete, and will probably never be superseded by any other method essentially different, still no one would think of asserting the impossibility of effecting any improvement. Many other modes of manufacture and several improvements of the old methods have been suggested, some of which deserve a brief notice.

A process invented by Mr. GOSSAGE, and for which he obtained a patent bearing date May, 1853, has for its object the purification of the black-ash liquors; firstly, by the oxidation of the sulphide of sodium; and, secondly, the separation of ferrocyanide of sodium from such liquors. During the ordinary process of evaporating black-ash liquors to dryness, and roasting the product so obtained, the sulphide of iron and the iron of the ferrocyanide of sodium become converted into oxide of iron; and this substance communicates an objectionable color to the soda ash produced, rendering it unfit for certain applications.

The sulphide of iron being held in solution by sulphide of sodium, if the latter salt be converted by oxidation into hyposulphite—$Na\,O, S_2\,O_2$—sulphite—$Na\,O, SO_2$—or sulphate of soda—$Na\,O, SO_3$—the sulphide of iron set free from combination becomes insoluble, and may be separated from the liquors by subsidence or filtration. In Mr. GOSSAGE's process, as stated in the specification of his patent, the oxidation of the sulphide of sodium in black-ash liquors is effected by causing them to absorb atmospheric oxygen. To effect this as quickly as possible the liquors are made to pass through a high tower, termed by the inventor an *oxidising tower*, which is filled with small pieces of coke, or other suitable material; and while the liquors are percolating, a current of air is at the same time caused to pass through the interstices between the pieces of coke, by connecting the upper part of the tower with a chimney. By this arrangement an immense number of surfaces moistened with the liquors is presented to the current of air drawn through the tower, and the absorption of oxygen is thereby greatly facilitated. After passing through the tower, the liquors are collected in a pan to which heat is applied, and are afterwards pumped up, and caused to flow again through the tower. These operations are repeated until the sulphide of sodium in the liquors has become completely oxidised. The sulphide of iron, now in an insoluble form, is to be separated from the liquors either by subsidence or filtration; and the menstrua being rendered perfectly colorless, are freed from all iron, except such as exists as ferrocyanide of sodium. When the black-ash liquors are to be used for the production of soda crystals, or of soda ash, the conversion of the caustic soda present into carbonate of soda, is, by a modification of the process, effected collaterally with the separation of the sulphide of iron. All that is necessary for this purpose is to cause carbonic acid gas to pass through the tower with the atmospheric air. The liquors so purified are to be concentrated by the usual method employed in the preparation of soda crystals, or so as to obtain salts therefrom. In the further treatment of these salts and the residual liquor, and also the salts obtained in a similar manner by evaporating the mother liquor from soda crystals, the second part of Mr. GOSSAGE's purifying process, namely, the separation of ferrocyanide of sodium, comes into operation. The first portions of the salts so deposited are but little impregnated with ferrocyanide of sodium; the second portions contain more of this compound; and the last portions are strongly impregnated with ferrocyanide, whilst the mother liquors still remaining contain a large proportion of this salt in solution. To separate it from these salts, they are to be washed with water or a solution of carbonate of soda.

For this purpose a series of four vats is employed, and the process is conducted exactly as in the lixiviation of black ash. In this mode of washing, the salts contained in each vat successively become those least impregnated with ferrocyanide, and are subjected to the first action of the water, or of the washing solution. The solutions obtained by such washings are mixed with the mother liquors of the salts; and if it be found by testing that the mixed liquors contain more than ten parts of carbonate of soda for each part of ferrocyanide of sodium present, they are to be concentrated so as to obtain a further quantity of salts therefrom; and this concentration and separation of salts is to be continued, as long as the proportion of ferrocyanide of sodium to the carbonate of soda is less then ten per cent. The salts obtained by this last concentration are to be introduced into the concentrating apparatus with fresh black-ash liquor. The liquors above referred to as containing ten per cent. less of carbonate of soda for each one part of ferrocyanide, are collected and mixed with sufficient water and caustic lime to convert the carbonate of soda present into caustic soda, and the solution so obtained is to be concentrated until the greater part of the ferrocyanide becomes separated as salt; or the separation of the ferrocyanide may be effected by allowing the concentrated solution to crystallize; or, instead of converting the carbonate of soda contained in the liquors into caustic soda, the solution may be impregnated with carbonic acid, when bicarbonate of soda, a compound of sparing solubility, will be formed, and the greater part of the ferrocyanide may be obtained by filtration of water through the same, and drainage. The solution of ferrocyanide now contains only a small proportion of soda, which is converted by means of lime into caustic soda, and from this the ferrocyanide is separated either as salts or by crystallization. By resolution in water and repeated crystallization, the ferrocyanide is obtained sufficiently pure to be suitable for use.

Mr. GOSSAGE's patent further includes a process for the production of caustic soda in a marketable state, in addition to white soda ash and ferrocyanide of sodium from black-ash liquors. In this operation, also, the liquors are first submitted to the oxidising action of atmospheric air as already directed. Any hyposulphate of soda contained in the purified liquors is then converted into sulphite or sulphate of soda by further oxidation; and this is effected by the gradual addition of solution of chloroxide of calcium, or bleaching powder. The liquors are now concentrated by the ordinary method so as to obtain salts therefrom; and these are washed as before described, to separate all the caustic soda and ferrocyanide of sodium. The mixed mother liquors and washings are then again concentrated, until the whole or nearly the whole of the carbonate of soda and ferrocyanide of sodium have become deposited as salts, and the solution or mother liquor remaining contains scarcely any saline matter but caustic soda. In this state it is suitable for many purposes to which caustic soda is applicable, and is a marketable product. The mixture of carbonate of soda and ferrocyanide of sodium in the form of salts, is washed with water by filtration; and the residue and washings are further treated exactly as before directed, for the preparation therefrom of pure soda ash and of ferrocyanide of sodium. By further concentration of the solution of caustic soda in cast-iron pans, it may be so far deprived of water as to become solid hydrate of soda when allowed to cool, and in this state it presents great facilities for transportation.

At a later date, namely in 1857, Mr. Gossage patented another invention, the object of which is to obtain an increased proportionate quantity of caustic soda or caustic potassa, or of carbonate of soda or carbonate of potassa, in the usual manufacture of soda or potassa. In the case of soda, this is effected, firstly, by using an increased proportionate quantity of small coal in the mixture employed, when decomposing sulphate of soda by fluxing. The proportions of these usually employed are three parts of sulphate of soda, three parts of carbonate of lime, and one and a half or two parts of small coal; but Mr. Gossage uses nearly equal weights of each of these materials, reserving some part of the small coal to be added as the decomposition proceeds. The decomposition of some part of the carbonate of soda produced is alleged to be effected in this way, and an increased proportionate quantity of caustic soda is obtained when the fluxed mass is lixiviated. It would appear, however, from what has been stated regarding the composition of black ash, that an increased ratio of the calcareous substance would be much more effectual.

The second part of the process consists in the addition to the solutions obtained, of hydrated oxide of iron, of zinc, of manganese, or of lead, whereby the sulphide of sodium present is converted into caustic soda, with simultaneous production of sulphide of the metal employed. The decomposition is effected by adding to the solution obtained by lixiviation at a boiling heat, such a quantity of the metallic oxide as is found, by testing the solution with a salt of lead, to be sufficient to remove the sulphur from the whole of the alkaline sulphide present. The metallic sulphide thus produced, after being washed with water, is decomposed by means of muriatic or some other suitable acid, and the metal is obtained in solution. This, decomposed by means of hydrate of lime or magnesia, yields the hydrated metallic oxide in a condition applicable to the decomposition of a further quantity of alkaline sulphide.

To obtain an increased proportionate quantity of carbonate of soda, instead of caustic soda, in the process of manufacture, the alkaline sulphide is to be decomposed by the addition of the carbonate of iron, zinc, magnesia, or lead, and the metallic sulphide produced is reconverted to the state of carbonate by the addition to the solution of the metal obtained, as before directed, of carbonate of lime or of magnesia. This process, it should be observed, is one of a series of improvements in the manufacture of soda patented by Mr. Gossage at the same time.

The primary object of these improvements is to render again available in the manufacture the sulphur contained in alkaline waste, which in the ordinary method is totally lost. As these relate more especially to the economical production of sulphuric acid, they will be further noticed in connection with the article to be specially devoted to that substance.

A process for impregnating black ash and white ash with carbonic acid, in order to convert the caustic and silicate of soda contained therein into carbonate, was patented some years ago by Mr. James Shanks. In applying this process to black ash, the latter is to be broken into fragments and disposed in several layers, each of three or four inches in depth, in a stone or iron vessel named the *carbonator*. The layers having been moistened with water, carbonic acid gas is admitted into the carbonator by a pipe, the air being allowed to escape by another one. When the odor of sulphide of hydrogen is strongly perceptible at the exit pipe, the whole of the soda is considered to be carbonated; the introduction of carbonic acid is then discontinued, and the black ash is removed to the vats and lixiviated in the ordinary manner. The lie prepared from black ash may be exposed to the action of carbonic acid instead of the ash. In this case the carbonator used should have a capacity of sixteen cubic feet for every ton of white ash, or six cubic feet for every ton of soda crystals, to be made daily. Across the bottom of the carbonator is thrown an open arch of brickwork, and the space above is filled with small pebbles, over which the solution to be carbonated flows, being admitted at the top. The carbonic acid is introduced below the arch, and allowed to rise in the carbonator between the pebbles, the air of the vessel escaping by a pipe at the top. The greenish-yellow or brown color of the liquor disappears when properly carbonated.

With the same object in view, Mr. John Wilson obtained a patent in 1840 for a process in which the caustic soda contained in either black or white ash is converted into carbonate by the application of as much bicarbonate of soda as might be necessary.

The entire loss of all the sulphur consumed as sulphuric acid in Leblanc's method of converting common salt into carbonate of soda, is justly considered a great objection to that process. Still, although numerous suggestions have been made, none of the new processes have succeeded so well as to supersede Leblanc's method; and the Editor is of opinion that it never will be supplanted. At the same time some of the plans recommended are so interesting in a purely theoretical point of view, that the Editor would scarcely be justified in omitting all notice of them.

One of the most economical of these processes is that proposed by Messrs. Hemming and Dyer, which is founded on the behavior of a solution of common salt with one of bicarbonate of ammonia. When carbonate of ammonia of commerce, which is in reality a mixture of carbonate and bicarbonate, is added in a state of fine powder to a solution of about an equal weight of salt in three parts of water, the mixture being well stirred, a white crystalline precipitate appears in a few hours, causing the liquid to become thick. This precipitate is bicarbonate of soda, and there is contained in solution chloride of ammonium, produced as shown in the annexed equation:—

$$\underbrace{\text{Na Cl}}_{\text{Chloride of sodium.}} + \underbrace{\text{NH}_4\text{O, 2 CO}_2}_{\text{Bicarbonate of ammonia.}} = \underbrace{\text{Na O, 2 CO}_2}_{\text{Bicarbonate of soda.}} + \underbrace{\text{NH}_4\text{ Cl}}_{\text{Chloride of ammonium.}}$$

In the manufacturing process founded on this reaction, common salt is mixed with an impure carbonate of ammonia, such as the liquor furnished by the purification of coal gas, or the distillation of bones; and, having separated the solid bicarbonate by pressure in a screw press, the chloride of ammonium remaining in the mother liquor is reconverted into bicarbonate of ammonia, by evaporating it to dryness, and treating the residue in a distillatory apparatus with carbonate of lime, as in the ordinary mode of preparing carbonate of ammonia. The advantage gained by this process is the production of soda without the use of sulphur, and therefore free from this element; the objection to it is the loss of ammonia, and also that the portion of chloride of ammonium necessarily remaining with the bicarbonate of soda, is in the heat *reconverted* into the cheap chloride of sodium. In referring to this method, PARNELL observes, that unless particular precautions be adopted, the loss of ammonia must be very great and inevitable, from two reasons:—First, when a mixture of chloride of ammonium and carbonate of lime is heated, a portion of the ammonia is always disengaged in the free state, the product not being a neutral carbonate, but a sesquicarbonate, having the formula $2\,NH_4O,\ 3\,CO_2$. In this process, therefore, one equivalent of ammonia in every three is disengaged in the free state and lost, unless particular means be adopted to retain it. Again, when the sesquicarbonate of ammonia is dissolved in water, it is resolved into the neutral carbonate and the bicarbonate; but chloride of sodium is decomposed by the bicarbonate only, and the neutral carbonate remaining in the mother liquor is decomposed during the evaporation into free ammonia and the bicarbonate, both of which are volatilized. The adoption of some patented improvements in the manufacture of carbonate of ammonia, in which the mixture of chloride of ammonium and carbonate of lime is impregnated with as much carbonic acid as it will absorb, whereby the sesquicarbonate of ammonia is wholly converted into bicarbonate, would also be a decided improvement on the preceding process of manufacture.

Other processes have been proposed for producing carbonate of soda directly or indirectly from common salt, and some of these were even known and practised before the discovery of LEBLANC'S method. Thus, in 1788, a French priest named MALHUBE proposed a process which was afterwards put in operation by ALBAN, and was practised in France during the Revolution. In this, one hundred parts of sulphate of soda are first reduced to sulphide of sodium by heating to redness with twenty parts of charcoal; and while the mixture is in the liquid state, twenty parts of iron turnings are added, then eight parts of charcoal or small coal, next twelve and a half parts of iron, and lastly three parts of charcoal. The caustic soda thus obtained is exposed to the air, to absorb carbonic acid. DUMAS considers it probable, that in this operation there is formed a double sulphide of sodium and iron, and that the sodium converted into caustic soda is not more than half that contained in the fluxed product. In another process, sulphate of soda is reduced to sulphide of sodium by heating it to redness with charcoal, and having dissolved the sulphide in water, carbonic acid is passed through the solution till sulphide of hydrogen ceases to be evolved. The carbonic acid is produced by burning charcoal or coke, or by calcination of limestone. According to DUMAS, to decompose sulphide of sodium by carbonic acid it is indispensable to use a considerable excess of the latter, so as to produce the bicarbonate of soda. Mr. GOSSAGE, however, states that he has succeeded in effecting the decomposition with such a proportion of carbonic acid as to produce the ordinary monocarbonate of soda. MARGRAAF suggested that carbonate of soda might be produced from the sulphide, by first converting the latter into acetate of soda by means of pyroligneous acid. When this is heated to redness, a residue remains, consisting of carbonate of soda and charcoal. LAMPADIUS proposed to form the acetate of soda by the addition to a solution of sulphate of soda, of one of acetate of lime, when insoluble sulphate of lime and acetate of soda are formed:—

$$\underbrace{Na\,O,\ SO_3}_{\text{Sulphate of soda.}} + \underbrace{Ca\,O,\ A}_{\text{Acetate of lime.}} = \underbrace{Na\,O,\ A}_{\text{Acetate of soda.}} + \underbrace{Ca\,O,\ SO_3}_{\text{Sulphate of lime.}}$$

KÖBUNTER proposes to form carbonate of soda by decomposing sulphate of soda with carbonate of baryta:—

$$\underbrace{Na\,O,\ SO_3}_{\text{Sulphate of soda.}} + \underbrace{Ba\,O,\ CO_2}_{\text{Carbonate of baryta}} = \underbrace{Na\,O,\ CO_2}_{\text{Carbonate of soda.}} + \underbrace{Ba\,O,\ SO_3}_{\text{Sulphate of baryta.}}$$

and KNAPP suggests that in districts where potassa is obtained at a moderate price, the production of saltpetre may be combined with that of soda, by decomposing Chili saltpetre—nitrate of soda—and carbonate of potassa into soda and ordinary saltpetre:—

$$\underbrace{NaO,\ NO_5}_{\text{Nitrate of soda.}} + \underbrace{KO,\ CO_2}_{\text{Carbonate of potassa.}} = \underbrace{Na\,O,\ CO_2}_{\text{Carbonate of soda.}} + \underbrace{KO,\ NO_5}_{\text{Nitrate of potassa.}}$$

In treating of caustic soda, several methods for producing that salt, both from chloride of sodium and other salts of soda, have been detailed. These have also been applied in the manufacture of carbonate of soda, the caustic having been subsequently combined with carbonic acid, either by exposure to the air, or by heating it with coal or sawdust, or in some other way. In the patent of Mr. JOHN WILSON for improvements in the manufacture of carbonate of soda, already quoted, there is included a mode of preparing carbonate of soda from sulphide of sodium. He effects the conversion by mixing a solution of the sulphide with one of the bicarbonates, in the proportion of forty-eight parts of the former to eighty-five of the latter salt. The change is shown in the annexed formula:—

$$\underbrace{Na\,S}_{\text{Sulphide of sodium.}} + \underbrace{Na\,O,\ 2\,CO_2}_{\text{Bicarbonate of soda.}} + \underbrace{HO}_{\text{Water.}} = \underbrace{2\,Na\,O,\ CO_2}_{\text{Carbonate of soda.}} + \underbrace{HS}_{\text{Sulphide of hydrogen.}}$$

If the sulphide of hydrogen gas thus disengaged is to be collected, the materials may be mixed in a covered iron pan, furnished with a pipe to conduct the gas to a gas-holder; but if the gas is not required the operation may be carried on in a common white-ash furnace. The mixture is evaporated to dryness, the residuary carbonate dissolved in water, and the clear solution is decanted and re-evaporated.

The soda process proposed and patented by MM. **Blanc** and **Bazille**, differs from nearly all the above-mentioned, inasmuch as the use of sulphur for the production of either sulphate of soda or sulphide of sodium is totally dispensed with. This method is founded on the decomposition of common salt by silica at a high temperature, and in the presence of steam. When the vapor of water is passed through an intimate mixture of common salt and silicious sand, contained in a porcelain tube heated to bright redness, the salt is decomposed, the chlorine unites with the hydrogen of the steam to form hydrochloric acid, which escapes as gas, while the sodium combines with the oxygen of the steam and with the silica or silicic acid, to form silicate of soda. The annexed equation represents the change :—

$$\underbrace{\mathrm{Na\,Cl}}_{\text{Chloride of sodium.}} + \underbrace{\mathrm{HO}}_{\text{Water.}} + \underbrace{\mathrm{Si\,O_2}}_{\text{Silicic acid.}} = \underbrace{\mathrm{Na\,O,\,Si\,O_2}}_{\text{Silicate of soda.}} + \underbrace{\mathrm{H\,Cl}}_{\text{Hydrochloric acid.}}$$

The decomposition, it will be observed, cannot take place unless water be present. In carrying out this process on a manufacturing scale, the patentees propose to introduce the mixture of salt and silicious sand into cast-iron cylinders, arranged in furnaces in a manner similar to gas retorts, so that the flame may play around and raise them to a cherry-red heat. A large perforated tube for the introduction of steam, as long as the cylinder, is to traverse the axis of each cylinder; and at one extremity of the cylinder the tubes must be each fitted to a large earthen or stoneware tube for the purpose of conducting the evolved hydrochloric acid to the condensers. The latter tube should be of considerable size, to prevent its being choked up with volatilized salt; and it should lead first into a large empty chamber in which the volatilized salt might be deposited; a communication between this chamber and the condensers may afterwards be established.

The cylinders thus arranged are to be loosely filled with an intimate mixture of twenty-eight parts of salt and twenty parts of fine sand, and raised to a cherry-red heat; steam being at the same time slowly and steadily admitted into the perforated tube from a boiler.

To remove the undecomposed salt from the mass so obtained, it is to be lixiviated with water, in which the silicate is scarcely soluble; and to procure this in a state of solution, it is first calcined at a red heat with about one sixteenth of its weight of soda ash, until the mixture is vitrified. The subsilicate of soda thus formed is dissolved in water; and from the solution carbonate of soda may be obtained by impregnation with carbonic acid, which causes the precipitation of gelatinous silica; the soda salt remaining in solution. The patentees prefer to procure the carbonic acid gas from the limestone by calcination in continuously acting limekilns. To the top of the kiln is adapted a dome-top, from which a tube passes into the vessel containing the solution to be carbonated; and it is alleged that the draught of the kiln is quite sufficient to maintain a proper degree of combustion to the end, if a single large vessel be employed to contain the solution instead of several small ones.

It is probable, as **Parnell** remarks, that the manipulations required in these operations would be too tedious, and the decomposition of the salt in the cylinders too slow and incomplete, to allow of the process being prosecuted successfully on a large scale.

A plan was proposed by **Maugham** for the production of silicate of soda, somewhat similar to the above, but with the additional aid of hydrofluoric acid. He then decomposes the silicate of soda by means of carbonate of lime.

Sesquicarbonate of Soda.—This salt exists as a natural product in solution in water. The mineral waters of Vichy and of Vals in France, of Bilin in Hungary, of Carlsbad in Bohemia, and the Geyser fountains in Iceland are remarkable examples. It is also produced as a mineral termed *trona* or *urao*, round the margin of some lakes in Northern Africa, Hungary, and South America. Its existence in nature is accounted for by some, on the supposition that chloride of sodium is decomposed by carbonate of lime, as **Berthollet** observed that whenever these two salts were found mixed together there was also an efflorescence of sesquicarbonate of soda. **Dumas**, however, dissents from this, and considers its formation to be owing to the decomposition of the sulphate of soda, which is always found in admixture with chloride of sodium. The sulphate of soda he supposes to be first reduced to sulphide of sodium by the action of organic matters in solution in the water; and the sulphide of sodium is afterwards converted into sesquicarbonate of soda by means of the carbonic acid also held in solution in the water of soda lakes. The lakes are usually called *white*, from the circumstance that, during the summer months, the water evaporating leaves a snow-white efflorescence on the surface at the bottom. This is sesquicarbonate of soda.

The plains on the shores of the Black and the Caspian Seas, Persia, Arabia, India, Thibet, China, and Siberia, and even the great desert of Africa—all furnish this variety of carbonate of soda.

This salt may be prepared artificially by several methods.

According to **Winckler**, if four ounces of alcohol be poured on the surface of a solution containing one hundred grains of simple carbonate of soda, and one hundred and fifty-two grains of crystallized bicarbonate of soda in four ounces of water; fine, clear, circular crystals of the sesquicarbonate are formed after several days at the surface of separation of the two liquids, and at the bottom of the solution large crystals of the simple carbonate are formed, together with a crust of bicarbonate of soda.

According to **Humann**, sesquicarbonate of soda cannot be prepared pure by crystallization from any aqueous solution, as it decomposes when in solution into the bicarbonate and carbonate of soda, which crystallize apart. When a concentrated solution of the bicarbonate is evaporated quickly, so as to avoid the dissipation of the whole of the second equivalent of carbonic acid; when the bicarbonate and crystallized carbonate are mixed in single equivalent proportions, and the mixture is caused to undergo the watery fusion; and, lastly, when the bicarbonate of soda is exposed to heat, the temperature not being allowed to exceed 482°, products are obtained, which consist for the most part of sesquicarbonate. If these masses are exposed for a few weeks to a humid atmosphere, they assume a perfectly crystallized structure; and their cavities and fissures become lined with groups of crystals, which are pure sesquicarbonate of soda. The form of the crystal of this salt is that of the rhombohedral prism, terminated by quadrangular pyramids. It dissolves in water more readily than the bicarbonate, but less easily than the simple salt, and the solution possesses an alkaline reaction. It is unalterable in the air, a remarkable proof of which is given by DUMAS, who asserts that the walls of Cassar, a fort in Africa actually in ruins, have been constructed with natural masses of this salt, originally obtained from some of the native lakes which abound in the country. It was formerly imported into this country, and sold under the name of *tronse*, and hence probably originated the error of the London college in substituting the sesquicarbonate for the bicarbonate of soda.

BICARBONATE OF SODA.—This salt may be obtained by passing carbonic acid through a concentrated solution of the simple carbonate; but the process is tedious and attended with much waste of gas, unless pressure be employed. Some manufacturers economize carbonic acid, by exposing the solution for a long period in shallow vessels to the atmosphere of a fermenting vat. In both cases bicarbonate of soda separates after some time in minute grains, owing to its comparatively sparing solubility; and the mother liquor, by cautious concentration at a temperature not exceeding 120°, yields a further quantity. In the process of SCHÖFFER, from three to four parts of crystallized carbonate are intimately mixed with one part of commercial sesquicarbonate of ammonia; the semifluid mass thus obtained, which evolves ammonia, is allowed to stand twenty-four hours, and then exposed to the sun on a clear surface. The last trace of ammonia escapes with the water, and bicarbonate of soda remains as a chalky mass. As the ammonia evolved in this method is lost, and as it is difficult to evolve in close vessels, SCHORZ proposed to mix fifty parts of dry carbonate of soda in fine powder with fifteen parts of the crystallized carbonate and forty-one parts of carbonate of ammonia, and to heat the mixture in a distilling vessel immersed in water.

The first nine-twelfths of the ammonia are readily evolved; the second two-twelfths with greater difficulty; and the last one-twelfth is removed by exposing the mass to the air. Manufacturers on the large scale have generally abandoned all the liquid processes for producing bicarbonate of soda, in favor of the dry way; and this is certainly preferable both as regards economy, convenience, and despatch.

The process commonly followed is that suggested by SCHÖFFER, and introduced into the Parisian codex of 1840. It consists in packing fragments of crystallized carbonate of soda upon a series of perforated shelves in a box, or in large air-tight iron cisterns without shelves, but with an airhole at the side, and a small pipe at the bottom to carry off the water of crystallization, which separates during the process. After the introduction of the salt, carbonic acid is admitted in a stream regulated according to the rate of its absorption. The carbonic acid may be derived by the decomposition of chalk or limestone by hydrochloric acid, or, with proper precautions, from a charcoal or coke fire, or from a liquor undergoing the vinous fermentation. The latter method may be advantageously practised in distilleries, where a great quantity of liquor is kept in a fermenting state for a considerable time.

As carried on in alkali works, the first method is the one usually practised; the muriatic acid obtained in the production of sulphate of soda being made to act upon chalk or limestone.

The evolution apparatus employed consists of a large stone cistern laid in clay and well bedded. It is provided with a pipe, continued to within a few inches of the bottom of the cistern, and through this the acid is admitted from the condensers. The cistern being filled with chalk, the acid is allowed to flow in, and, rising through the mineral, it disengages carbonic acid in the passage; and the solution of chloride of calcium formed escapes through another pipe, similar to that by which the acid is admitted. The escaping liquors flow off through a third pipe, and the carbonic acid issues through an opening, whence it is conducted to the cisterns or boxes containing the crystallized carbonate of soda. The gas coming in contact with the crystals is very rapidly absorbed; and at the same time a liquid, charged with carbonate of soda or sesquicarbonate, trickles down to the bottom of the cistern, owing to the carbonate containing more water of crystallization than is required to constitute the bicarbonate. This liquid is usually withdrawn from time to time, as may be necessary. During the absorption of the gas a considerable amount of heat is evolved; and at the end of ten days or a fortnight the whole is converted into bicarbonate of soda, which is, however, very damp. This moisture is removed by heating the mass in stoves fitted with wooden shelving, by air passed through hot iron pipes.

A great improvement on this method in small operations, and which has also been adopted on the large scale, is the process suggested in its details by MOHR. In this method, the crystallized and anhydrous carbonates are mixed in such proportions as to leave a slight excess of water over what is necessary for the water of crystallization of the whole salt, when it is converted entirely into bicarbonate; and carbonic acid is admitted to the bottom of the mixture by a tube proceeding from a pneumatic apparatus similar to a gasometer, so constructed that there can never be any waste of gas. The absorption is completed every twenty-four hours.

MOHR proposed to mix anhydrous carbonate so as to leave no excess of water over that required for the water of crystallization of the bicarbonate. CHRISTISON, however, who carefully investigated the subject, found that absorption does not take place at all with the proportions proposed by MOHR; that with nothing but crystallized carbonate the absorption is slow, and the disengaged water contains carbonate or sesquicarbonate; but that with such proportions of the crystallized and anhydrous carbonates as will leave a slight excess of water, absorption is prompt, a slightly damp salt results, and there is not an appreciable quantity present of any other carbonate besides the bicarbonate.

The rapidity with which effloresced carbonate of soda, or what is practically the same, a mixture of crystallized and anhydrous carbonate, absorbs carbonic acid, is stated by ARTUS to be considerably increased by mixing with the salt recently calcined and powdered charcoal, made from soft wood, which possesses the power of condensing gases within its pores to an extraordinary extent. When it is desired to obtain the bicarbonate in crystals, advantage may be taken of this property of charcoal. The mixture, which may be made in the proportion of two parts of effloresced carbonate and one part of charcoal, is moistened and exposed to the gas for twenty-four hours, then taken out, powdered, and moistened, and again exposed to the gas. These operations having been twice repeated, the mass is mixed with eight parts of hot water; the solution is filtered while hot, and left for the bicarbonate to crystallize. Carbonate of soda is known to be fully saturated with carbonic acid when it no longer reddens turmeric, or gives a precipitate with a very dilute solution of chloride of mercury or corrosive sublimate, but with a concentrated solution a white precipitate, which becomes red in a few minutes, and afterwards purple; with the least admixture of simple carbonate of sesquicarbonate of soda, the precipitate is reddish-brown.

Bicarbonate of soda is known only in combination with water, its formula being—$\mathrm{Na\ O,\ 2\ CO_2,\ HO}$. It crystallizes in oblique four-sided tables, which have a slightly alkaline taste and a very feeble alkaline reaction on vegetal colors. As met with in commerce, it is usually in the form of powder, or in small, white, opaque, irregular scales. At a moderate heat, it loses half its carbonic acid and the whole of its water, and is reduced to the state of anhydrous monocarbonate. Cold water dissolves about one-tenth of its weight, and hot water considerably more. When the solution is heated somewhat above 120°, carbonic acid begins to be eliminated; and, according to BERZELIUS, at 212° the salt becomes sesquicarbonate.

Physiological Effects.—Bicarbonate of soda possesses diuretic properties, but less actively than the corresponding salt of potassa. It is also an excellent antacid and antilithic, and is employed in great quantity for making effervescing powders. A mixture of this salt with the tartrate of soda and potassa, or Rochelle salt, with the addition of tartaric acid, constitute seidlitz powders. Many have thought that the long-continued use of alkaline carbonates in gravel and acidity of the stomach entails injurious consequences; and diseases of the kidneys as well as organic disorders of the stomach have been referred to the practice. These suppositions are probably imaginary, as there can be no question that many have employed alkaline remedies habitually for years, without apparently any deleterious effects being produced; the Editor can affirm this from his own experience.

HYPOCHLORITE OF SODA—CHLORIDE OF SODA—CHLOROXIDE OF SODIUM.—A solution of this salt in an impure state constitutes the well-known disinfectant liquor of LABARRAQUE. Its disinfecting power was discovered about the year 1820. The process for preparing this solution given in the London Pharmacopœia is as follows:—A pound of crystallized carbonate of soda is dissolved in two parts of water, and the chlorine eliminated by heating a mixture of four ounces of common salt, three ounces of binoxide of manganese, four of sulphuric acid, and three of water, is conducted into the solution. The changes that ensue are represented in the subjoined formula, the result of the decomposition being a mixture of bicarbonate of soda, hypochlorite of soda, and chloride of sodium:—

$$\underbrace{4\,(\mathrm{Na\ O,\ CO_2})}_{\text{Carbonate of soda,}} \quad + \quad \underbrace{2\ \mathrm{Cl}}_{\text{Chlorine,}} \quad = \quad \underbrace{\left(\mathrm{Na}\left.\begin{matrix}\mathrm{O}\\ \mathrm{Cl}\end{matrix}\right\}\right)}_{\text{Chloroxide of sodium,}} \quad +$$

$$\underbrace{2\ \mathrm{Na\ O\ 2\ CO_2}}_{\text{Bicarbonate of soda.}} \qquad \underbrace{\mathrm{Na\ C}}_{\text{Chloride of sodium,}}$$

The above is the method followed in the preparation of this salt by LABARRAQUE; PAYEN proposed another, which was adopted by the French pharmaceutists. It consists in the decomposition of chloroxide of calcium, or bleaching powder, by carbonate of soda. The proportions employed are one part of bleaching powder and thirty of water, and for the carbonate of soda solution two parts of the crystallized carbonate and fifteen of water. In this process hypochlorite of soda and chloride of sodium are formed, and remain in solution whilst carbonate of lime is precipitated. By using the proportion of the French Codex, the solution obtained is much weaker than that prepared as directed by the London College. Pure hypochlorite of soda can only be obtained by neutralizing a solution of hypochlorous acid with one of soda.

LABARRAQUE'S disinfecting compound may be obtained in the solid state, according to MAYER and SCHINDLER, by transmitting chlorine, evolved from ten parts of common salt, eight parts of binoxide of manganese, and fourteen parts of sulphuric acid, into nineteen parts of dry powdered carbonate of soda, moistened with one part of water only. The absorption of chlorine goes on slowly with the disengagement of heat.

Properties.—The solution known as LABARRAQUE'S disinfecting fluid is colorless or slightly yellow, has an odor of chlorine and an astringent taste. Upon vegetal coloring matter it first reacts as an alkali, and afterwards effects its destruction. By evaporation needle-shaped crystals are obtained, which when redissolved in water reproduce the bleaching fluid. Acids added to the solution disengage chlorine and carbonic acid gas, and by exposure to the air decomposition is also effected, and crystals of carbonate of soda are formed.

Physiological Effects.—This salt, as well as the soluble hypochlorites, is supposed to exercise a specific influence over the nervous system, causing depression and tetanus. In small doses it has been considered to possess tonic, alterative, and febrifuge properties, and has, consequently, been proposed as a remedy in strumous diseases, chronic affections of the liver, ague, and the typhoid form of continued fever. Its utility as an external remedy is, however, much better established than its alleged therapeutic properties as an internal agent. When considerably diluted it is an excellent stimulant for ill-conditioned sores on the surface of the body, and especially for promoting cicatrization.—*Christison.*

According to PEREIRA it is most valuable as a disinfectant antiseptic, and as an antidote in cases of poisoning by the sulphides and by hydrocyanic acid; and he remarks, that in several cases where he had carefully compared it with chloroxide of calcium he gave the decided preference to the chloroxide of sodium. LABARRAQUE recommends its employment as an antiseptic, on the ground that by the process of disinfection it becomes chloride of sodium, which is not a deliquescent salt, whereas the chloride of calcium existing in and generated by bleaching powder, attracts water from the atmosphere, and thereby furnishes one of the conditions necessary to the putrefactive process. Hence, in his opinion, while chloride of lime will serve equally well for mere disinfection, chloride of soda is preferable when one wishes at the same time to prevent a renewal of putrefaction.

HYPOSULPHITE OF SODA.—There are several modes of procuring this salt. It is very conveniently prepared by first forming a solution of neutral sulphite of soda, by passing sulphurous acid gas into a strong solution of the carbonate of this base. The sulphite so obtained is then digested with sulphuric acid for several days at a moderate heat. In this case sulphurous acid, by taking up sulphur, becomes hyposulphurous acid, thus—

$$\underbrace{SO_2}_{\text{Sulphurous acid.}} + \underbrace{S}_{\text{Sulphur.}} = \underbrace{S_2O_2}_{\text{Hyposulphurous acid.}}$$

Or a solution of soda may be first saturated with sulphur by boiling, and sulphurous acid may then be passed through this menstruum, when hyposulphite of soda is formed. In either case the solution obtained is rapidly evaporated to a sirupy consistence and then set to repose, when the hyposulphite separates in large colorless crystals.

A very convenient process for the production of this salt on the small scale is that recommended by WALCHNER. A pound of pure crystallized carbonate of soda is dried as perfectly as possible, and then intimately mixed with five ounces of pure sulphur; the mixture is gradually heated in a glass or porcelain basin to the melting point of the sulphur, and kept at that temperature for some time, stirring constantly in order to bring every part in contact with the air. The sulphide of sodium formed at first absorbs oxygen from the air, and is converted with feeble incandescence into hyposulphite of soda. The mass, when cold, is dissolved in water boiled with sulphur for some time, and the filtrate is evaporated, when very fine and pure crystals separate. If the heat employed be too strong, part of the sulphur is burned off, and carbonate of soda remains undecomposed. In this case a second crystallization is necessary.

Properties.—Crystallized hyposulphite of soda—$NaO, S_2O_2, 5HO$—is an inodorous salt with a taste first cooling, and afterwards bitter. The crystals are oblique prisms, belonging to the right prismatic system. They are deliquescent in the air, but *in vacuo* lose their water of crystallization. When heated, the salt at first undergoes the aqueous fusion, and then dries up into a white mass; the heat being continued, it takes fire, burning vividly and with a clear yellow flame. Hyposulphite of soda is readily soluble in water, but not in alcohol. In close vessels the aqueous solution deposits sulphur till nothing but sulphite of soda remains in the liquid; exposed to the air it deposits sulphur, and the sulphite is converted into sulphate of soda.

Hyposulphite of soda, and other soluble salts of hyposulphurous acid, possess the remarkable property of dissolving all the compounds of silver, even the chloride, and the solution thus formed has a very intense sweet taste, with a metallic after-taste. This property has been made available in the daguerreotype, for the purpose of dissolving the sensitive coating of iodide from the plate of silver after exposure to light, and thus fixing the image already formed. For this purpose hyposulphite of soda is now prepared on a very considerable scale.

ANALYSIS.—The compounds of sodium may be distinguished from all other salts in a most unmistakable manner, though the tests are almost of a purely negative character. In the pure state, the mode of recognition is as follows:—When dissolved in water, no precipitate or other change is produced by the addition of hydrochloric acid, sulphide of hydrogen, sulphide of ammonium, carbonate of ammonia, or bichloride of platinum; but if the solution be evaporated to dryness, or if a little of the original substance be taken and exposed on a platinum wire to the inner frame of the blowpipe, the outer flame becomes of an intense yellow color, owing to the reduction of the soda and the subsequent oxidation of the reduced sodium.

This test is a safe, and mostly in itself sufficient proof of the presence of soda, provided always a fixed alkali alone be present and in the form of chlorides; the one hundredth part of soda may by this means be detected in presence of potassa. A precipitant has been proposed for soda, which is not, however, of any great value, and is very rarely employed; this is the antimoniate of potassa. It produces, in neutral or alkaline solutions of salts of soda, a white crystalline precipitate of antimoniate of soda, which in concentrated solutions is formed immediately, but in dilute solutions, only after the lapse of some time. Its formation is promoted by vigorous shaking of the mixture. This test gives decisive results only when applied with a careful and attentive consideration of the attendant circumstances. The most indispensable condition of its applicability is, that besides soda and potassa, no other bases must be present in the solution, since the salts of the heavy metallic oxides, those of the earths proper, and of the alkaline earths, and finally those of ammonia, are also thrown down by antimoniate of potassa. The solutions, too, must be neutral or alkaline, since otherwise the reagent suffers decomposition, and hydrated antimonic acid or acid antimoniate of potassa is precipitated from it. Soda is usually estimated quantitatively as sulphate of soda or as chloride of sodium.

Other compounds of soda are converted into sulphate by adding to their aqueous solution a quantity of sulphuric acid more than sufficient to saturate the whole of the soda; the solution is then evaporated to dryness, and the excess of sulphuric acid expelled by ignition, adding now and then a portion of carbonate of ammonia.

Every one hundred parts of sulphate of soda so obtained represent 43·66 of soda. Of chloride of sodium obtained in a similar manner, one hundred parts represent 39·34 of sodium, or 53·02 of soda. Salts of soda are also sometimes determined as carbonate of soda; and for soda salts with organic acids this method is preferable to all others.

Caustic soda is converted into carbonate by adding to its aqueous solution carbonate of ammonia in excess, evaporating at a gentle heat, and igniting the residue. The bicarbonate of soda is converted into the simple carbonate by ignition; and the salts of soda with organic acids are converted into the carbonate by heating gradually in a covered crucible, the charcoal being afterwards removed by igniting the residue in a gentle current of air. Every one hundred parts of carbonate of soda obtained represent 58·49 of soda.

Lastly, the determination of the commercial value of some soda compounds, as soda ash, caustic soda, borax, *et cetera*, is effected by noticing the quantity of acid of known strength required to neutralize a given weight of the salt. The process recommended by Mr. FARADAY is as follows:—Into a tube of about three-quarters of an inch in diameter, and nine and a half long, and as cylindrical as possible throughout its whole length, one thousand grains of water are to be weighed, and the space occupied marked on the tube with a fine file; this space is then divided from above downwards into one hundred equal parts. At 23·44 or 76·56 parts from the bottom an extra line should be made, and soda marked opposite to it; at 48·96 potassa should be marked in the same way; at 54·63 carbonate of soda; at 65 carbonate of potassa. A diluted acid is now to be prepared, which shall have a specific gravity 1·127, and this is made by mixing intimately together nineteen parts by weight of oil of vitriol and eighty-one of water. The method to be followed in the employment of this acid is as follows:—The dilute acid is to be measured in the tube up to the line opposite to which the alkali sought for is marked; if barilla, which contains carbonate of soda, 54·63 measures are to be taken. The one hundred measures are then made up by the addition of water, and is then ready for use. But these processes, which constitute a very important branch of commercial analysis, have been fully discussed under *Alkalimetry* in connection with the article POTASSA, Vol. II., page 729 *et seq.*, to which the reader is referred for details.

STATISTICAL REPORTS OF THE ALKALI TRADE OF THE UNITED KINGDOM FOR THE YEAR 1852, DRAWN UP BY J. WILLIAMSON, ESQ., JARROW CHEMICAL COMPANY, SOUTH SHIELDS,

From full returns by sixteen manufacturers, representing 46°/o of the trade.
From partial returns by eleven manufacturers, representing 35°/o "
No returns by sundry manufacturers, representing 19°/o "

RAW MATERIAL CONSUMED, IN TONS.

	Newcastle-on-Tyne.	Lancashire.	Glasgow and the Clyde.	Wales, Ireland, and South of England.	Midland.	Total.
Sulphur,	7,580	none	3,000	none	940	11,520
Pyrites,	33,750	40,220	9,000	12,000	5,292	100.262
Salt,	57,905	40,152	19,120	12,000	8,370	137.547
Coals,	232,020	136,400	80,000	36,500	34,500	519,420
QUANTITY OF PRODUCE, IN TONS.						
Alkali,	23,100	26,343	12,000	7,000	2,750	71,493
Crystal soda,	42,794	3,500	6,000	3,500	5,250	61,044
Bicarbonate of soda,	4,046	1,200	none	none	516	5,762
Bleaching powder,	5,000	1,250	5,000	1,850	none	13,100
Number of men employed,	3,067	1,519	900	470	370	6 326
Amount expended in apparatus,	£344,000	172,000	100,000	50,000	36,000	702,000
Amount annually expended in repairing the same,	£69,500	23,000	20,000	11,000	6,200	129,700
Tonnage of shipping employed,	189,100	71,200	70,000	35,000	8,000	373,300

71,193	tons alkali, at £10,	£711,930
61,044	" crystal soda, at £5,	305,220
5,762	" bicarbonate of soda, at £15,	86,430
13,100	" bleaching powder, at £10,	131,000
	Total value of products,	£1,234,580

VALUE OF MATERIALS IMPORTED FROM OTHER COUNTRIES.

11,520	tons sulphur, at £6,	£69,120
4,800	" nitrate of silver, at £15,	72,000
12,000	" manganese, at £2 10s.,	30,000
		£171,120

Amount contributed by the alkali trade to the annual income of this country, £1,063,460.

This report is the only accurate return ever made of the alkali trade. The manufacture in Lancashire has, however, greatly increased of late years; but if the total amount given be doubled, the figures will represent pretty nearly the present yield of the manufacture.

STARCH.—*Amidon*, French; *Sterke*, German; *Amylum*, Latin.—Starch exhibits to the naked eye the appearance of a white glistening powder, which, under a higher visual power, is found to be composed of a number of very minute, colorless, and semitransparent grains. It is a secretion educed from most plants and seeds, though contained in some in much greater proportion than in others; and it would appear that its end is to produce cellular structure under the vital power of the plant, as well as to give support to the embryo seed till it is able to gather sustenance from extraneous sources.

History and Sources.—This substance has long been known: the ancient Greeks called it *αμυλον*, from the circumstance of its not being prepared by grinding in mills like other farinaceous matters. Pliny attributes to the inhabitants of the island of Chio the discovery of the method of extracting it from wheat flour. Very little is said concerning it in any historical work down to modern times. Fosbroke states that starches of various colors were imported into England from Holland in 1564—that which was yellow being esteemed the best for ruffs and other articles.

The starches more commonly known as products of particular seeds or parts of plants, are in a measure restricted to a definite number of organic productions, which secrete them for the purposes already alluded to; but if by starch be meant the analogues of this substance, having the same or a closely allied composition, then it may be said to form a constituent of all plants at one stage or another of their existence. The fact that starch of one form or other enters at some particular period into the composition of plants, is the more certain from the consideration of the variety of starches and their congeners. Of these there are three kinds known, namely, *common starch*—such as is extracted from the monocotyledonous and bicotyledonous seeds, and from several roots, tubers, *et cetera*—also *lichen starch*, and *inulin*. The first is the primary link between cellulose and dextrin or artificial gum; the second is intermediate between cellulose and dextrin; and inulin is the connecting link between common starch and sugar. On examining the transformations which the seeds of many plants, such as the cereals, the tubers, or leguminous plants—seeds which are rich in starch—undergo when germinating, it is evident that they effect the solution of the substance of the amylaceous matter into gum, or dextrin, or sugar, whence the carbon necessary for the increase of the young germ is extracted; and so likewise the starch which is abundant at one period of the growth of plants, but which at a more advanced stage disappears, must have passed through an analogous modification necessary for the development of another secretion. This department of vegetal physiology is, however, not sufficiently investigated to admit of explaining with certainty the intermediate stages of the secretion and decomposition of the starch granules in plants; but the fact that starch appears at one period of the growth of a plant or the formation of a fruit, and disappears at another, warrants the supposition that where sugar or gum is discovered, starch, organized in the form of granules or in some other stages, has probably preceded these, or will result from them.

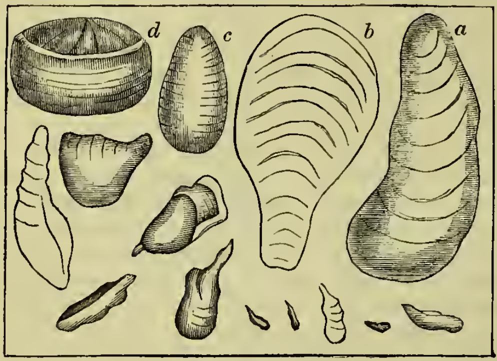
The term starch may be used here in a generic sense to designate the variety of organized structures educed from seeds, roots, and stems of plants belonging to different orders and families, in consequence of such educts offering marked analogies of properties and composition, though differing in physical characters. When it is requisite to distinguish the particular kinds, the source is mentioned; hence wheat, potato, arrow-root, sago, rice, and other starches. Wheat starch is generally called *amidon*, which term is applied not only to the amylaceous matter educed from wheat, but likewise to the similar products of the other seeds of the cerealia in the grains of the leguminosæ, the chenopodiaceæ, *et cetera*. Potato starch has its synonym in *fecula*, and this also is the term by which the starch from the carrot, beet, yam, and the like, are distinguished from the foregoing, as likewise arrow-root, sago, and other kinds. Arrow-root starch is found in the roots of many plants belonging to the family of *Scitamineæ zingiberaceæ* and *euphorbiaceæ*, as the *maranta arundinacea*, and *indica*, from which it is extracted in Jamaica; and the *curcuma angustifolia* from which it is prepared in the East Indies. Sago starch exists in the pith of the palm tribe, especially the *Sagus Rumphii*, *Cicasinermis*, *C. revoluta*, *Coryota urens*, *Borassus gomato*, and several species of *Zamia*, *Corypha*, and *Mauritia*, and can be extracted from them. Besides these, there is another variety of amylaceous secretion, which, differing from them in physical characteristics, is still allied to the preceding in chemical composition, and this is known as *inulin*. It is the immediate principle extracted from the roots of many plants, as the *dahlia*, *elecampane*, *inule*, *helenium*, *colchicum*, *dandelion*, *chicory*, *Iceland moss*, *Carrigeen moss*, and several of the lichen and fucus tribe of plants. The latter is little used in the industrial arts of Europeans, though employed in China for the manufacture of transparent lamps and tablets similar to the gelatin articles of the French.

Physical Properties.—Particles of starch viewed under a high magnifying power, appear in well-defined grains, in most cases more or less oval; in others polygonal. Notwithstanding an evident analogy between starch particles, from whatever sources obtained, there still remains such difference in their shape and size as to enable any person acquainted with them to identify any particular species even when mixed with others from a different source. Size is the most important criterion, and Payen's researches in measuring the relative magnitude of the starch granules from various sources, constitute perhaps the best guide for the student; hence the following measurements and engravings of the appearance of the various starches, from his *Chimie Industrielle*, will be found useful. The details are of forty-one varieties:—

Fig. 523.—Fecula of the *Canna gigantea* measure in length 175 thousandths of a millimetre—equal seven thousandths of an inch, the millimetre being 0·03937 of an inch; *a*, *b*, *c*, *d*, *e*, represent the normal starch granules; f, f', f'', granules partly exfoliated by vegetation which wastes them. The grains of the

Columba roots—*Minispermum palmatum*—measure 180 thousandths of a millimetre, and those of the large ripe potato—of Rohan—185 thousandths of a millimetre.

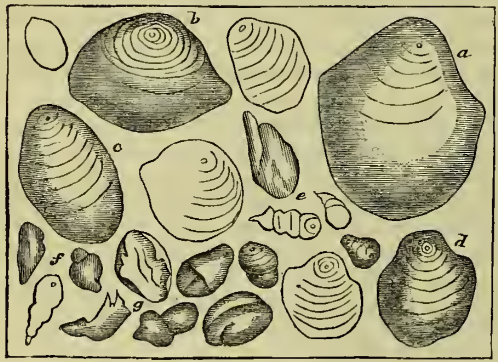
Fig. 523.



Case 1.

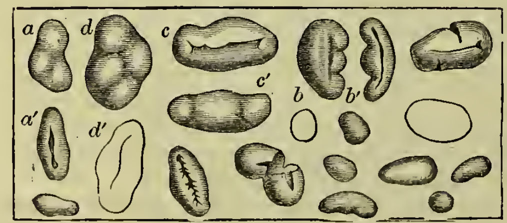
Case 2.—Fecula of the arrowroot of commerce—*Maranta arundinacea*—attains a length of 140 thousandths of a millimetre; *a, b, c, d,* represent the normal external coating separated from the inclosed matter by pressure. Fecula from the bulb of the lily has the same dimensions.

Fig. 524.



Case 2.

Fig. 525.



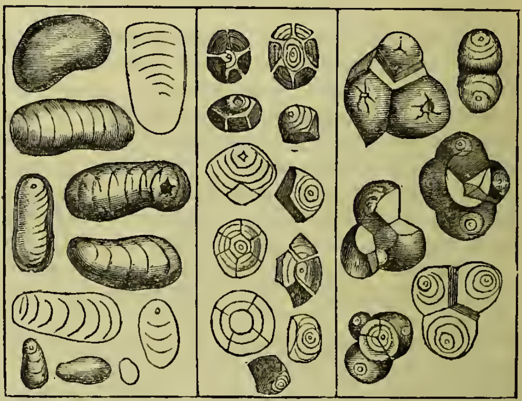
Case 3.

Case 3.—Bean starch, the maximum length of which is 75 thousandths of a millimetre—three thousandths of an inch. At *a a′, b b′, c c′, d d′,* the granules are seen in two positions, exhibiting length, breadth, and depth, and also the median canalled impression.

Case 4.—Starch from the tubercles of the *Oxalis crenata*, 85 thousandths to 100 thousandths of a millimetre. Fecula from the largest *Echinocactus erinaceus* imported, 75 thousandths of a millimetre.

Cases 5 and 6.—Detached and agglomerated grains of the pith of the *Cycas circinalis*—sago—the length of the largest of which measures 50 thousandths of a millimetre.

Fig. 526.

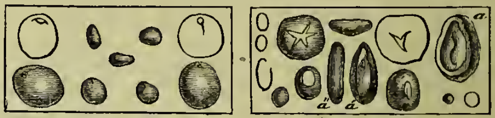


Case 4. Case 5. Case 6.

Case 7.—Wheat starch granules, *a, a′, a″,* in three positions, the largest of which are from 45 to 50 thousandths of a millimetre.

Case 8.—The same starch, the orifice or *hilum* of which is rendered visible by heating to 396°, and examining the granules subsequently in alcohol of 0·85 specific gravity.

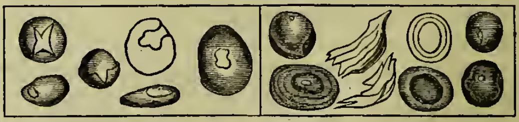
Fig. 527.



Case 8. Case 7.

Case 9.—The same starch viewed after the evaporation of the alcohol, showing where the residual water has dissolved a portion of the exterior of the globule.

Fig. 528.



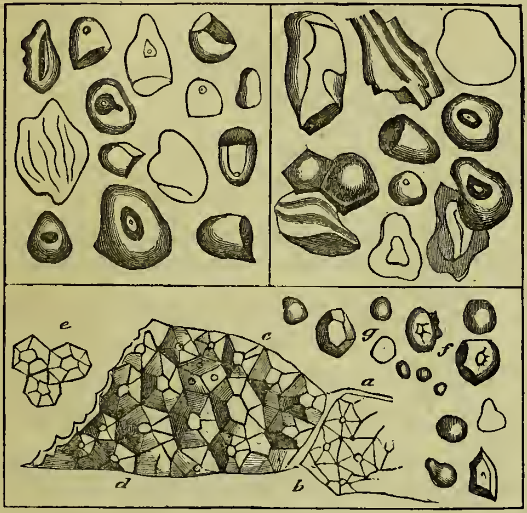
Case 9. Case 10.

Case 10.—The same starch after the internal matter has been dissolved by an excess of water.

Case 11.—Fecula of the red sago of commerce, the grains of which are partly swollen and deformed by heat.

Case 12.—Fecula of white sago, showing the alterations suffered in the preparation by the effects of a high temperature and the presence of a large quantity of water; this variety, as also lentil starch, measures 75 thousandths of a millimetre; kidneybean or haricot starch 67 thousandths; and that of large peas 36 thousandths of a millimetre.

Case 11. Fig. 529. Case 12.

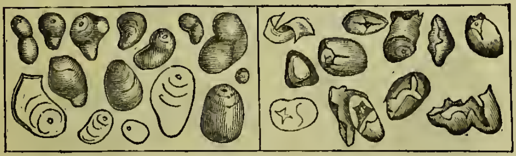


Case 13.

Case 13.—Indian corn starch. Here *a b*, *c d*, represent the grains encased and compressed in two contiguous cells of the horny part of the perisperm; *e*, *e*, *e* represent three compressed grains; *f*, *g*, detached grains, 25 to 30 thousandths of a millimetre.

Case 14.—Fecula of the bulb of the hyacinth, showing several double grains; the greatest length is 45 thousandths of a millimetre.

Fig. 530.



Case 14 Case 15.

Case 15.—The same, showing the exfoliation of the granules in an old shell.

Case 16.—Fecula of beet, showing several double grains and appearing conical; length 40 thousandths of a millimetre.

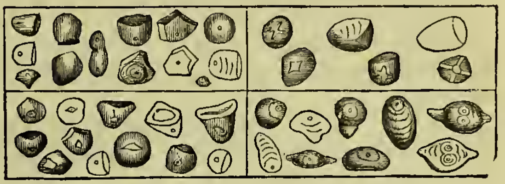
Case 17.—Shows the same heated to 360° to develop more plainly the hilum or aperture.

Case 18.—The same fecula as it appears at the commencement of its hydration after the evaporation of the alcohol.

Case 19.—Fecula of the *Orchis bifolia*, many granules of which have two apertures or hila, and double lateral conical protuberances.

Case 20.—Fecula of the *Orchis latifolia*, the grains of which are ovoidal, pear-shaped, *et cetera*, with a double hilum. Both these kinds of starches measure 45 thousandths of a millimetre.

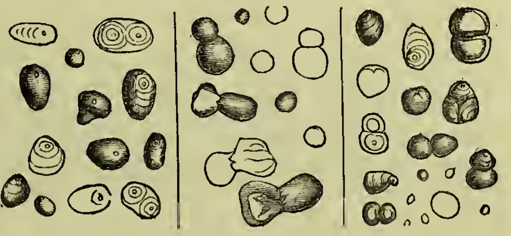
Case 16. Fig. 531. Case 18.



Case 17. Case 19.

Case 21.—Starch grains found in the tubercle of the potato, the growth of which was arrested. The granules are seen forming two or more smaller corpuscles at the expense of the larger ones; also the more developed grains, several of which are adhering two and two together, with a few grains acted upon with a solution of soda containing 0·005 of the caustic alkali, and swelling the matter in the interior so as to cause it to exude.

Fig. 532.

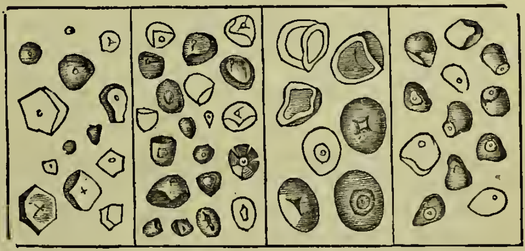


Case 20. Case 21. Case 22.

Case 22.—Fecula extracted from the stem of the *Cactus Peruvianus*, showing the single, double, and triple grains. It measures from 25 to 30 thousandths of a millimetre.

Case 23.—Represents the starch of the red sorgho, most of the grains of which exhibit a polygonal outline, and measure 30 thousandths of a millimetre. The amylaceous organization of the *Cactus pereskia grandiflora* are of the same size, as also that of the *Naïas major*.

Fig. 533.



Case 23. Case 24. Case 25. Case 26.

Case 24.—Starch grains of the *Aponogetum dis-*

tachyum of a truncated polygonal form; they measure 22 thousandths of a millimetre. Such also is the dimension of the starch contained in the stem of the *Ginko bilobi—saliburia adianthifolia.*

Case 25.—Exhibits the same swollen by a solution of soda.

Case 26.—Shows the starch of the *Cactus cercus grandiflora,* and which measures 20 thousandths of a millimetre.

Case 27.—Fecula of the *Cactus Braziliensis,* showing the double and triple grains; it measures 18 thousandths of a millimetre.

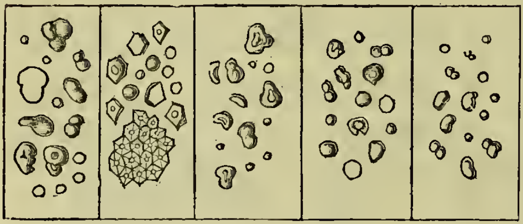
Case 28.—Starch of the *Panicum Italicum* in polygons; measures 16 thousandths of a millimetre.

Case 29.—Fecula of the *Cactus flagelliformis,* measures 15 thousandths of a millimetre. The pollen of the *Globba nutans* has the same dimension.

Case 30.—Starch of the *Echinocactus erinaceus,* measures 12 thousandths of a millimetre. Pollen of the *Rupia maritima* is 11 thousandths of a millimetre.

Case 31.—Starch of the *Cactus opuntia tuna* is 10 thousandths of a millimetre. The starch of the *Ficus indica,* as also that of the *Cactus curassavicus,* have the same dimensions.

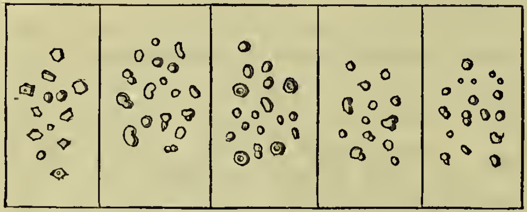
Fig 534.



Case 27. Case 28. Case 29. Case 30. Case 31.

Case 32.—Starch of the *Aylanthus glandulosa* measures 7 to 8 thousandths of a millimetre.

Fig. 535.



Case 32. Case 33. Case 34. Case 35. Case 36.

Case 33.—Represents the starch grains of the *Cactus curassavicus.*

Case 34.—Starch from the parsnip, measuring 7 thousandths of a millimetre.

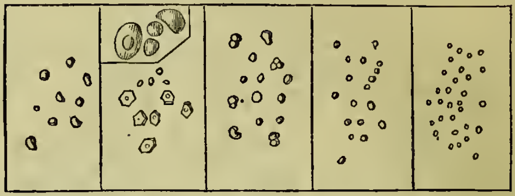
Case 35.—Shows the granules of the *Ficus indica.*

Case 36.—Shows the double starch granules of the *Cactus serpentinus,* 7 thousandths of a millimetre.

Case 37.—Fecula of the *Cactus monstruosus,* measuring 6 thousandths of a millimetre.

Case 38.—Millet starch—*Panicum miliaceum*—exhibiting the polygonal form; they measure 9 thousandths of a millimetre. The inclosed grains are those that have been swollen with a solution of soda.

Fig. 536.



Case 37. Case 38. Case 39. Case 40. Case 41.

Case 39.—Starch of the *Cactus mamillaria discolor* exhibiting several double grains; length 8 thousandths of a millimetre.

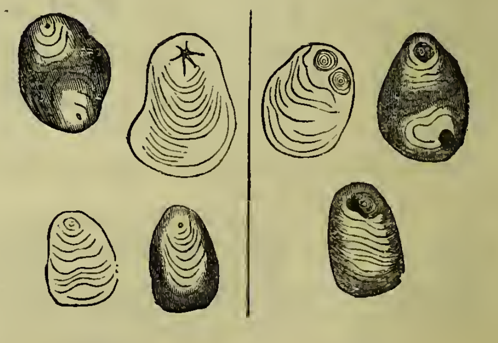
Case 40.—Starch grains of the sugar beet, exhibiting a globular form; the largest measure 4 thousandths of a millimetre.

Case 41.—Starch from *Chenopodium quinoa,* of rounded form, measuring only 2 thousandths of a millimetre.

Thus it will be seen, that the most general forms of starch corpuscles are ovoidal, conical, and polygonal; the first and second shapes prevail when the cellular structure, in which the granules are inclosed, offers sufficient space and retains as much moisture as to confer elasticity upon the coats and interior substance of the grain; but sometimes the granules are collected in large numbers in the cells of the seed or plant, which in turn are closely bedded in the *testa* or outer covering; in such cases—as shown in Case 13 in preceding plate—the compression causes the walls of the amylaceous bodies to assume polygonal forms.

Schleiden and others describe the formation of a starch corpuscle as commencing from a spheroidal granule, the nature of which is assumed to be different from the matter subsequently secreted. This matter, according to Payen, is assimilated through a funnel-shaped opening in the granule, usually, though improperly, called a *hile* or *hilum.* This aperture is visible in many varieties, and sometimes grains are found to have two or three of them, especially when the

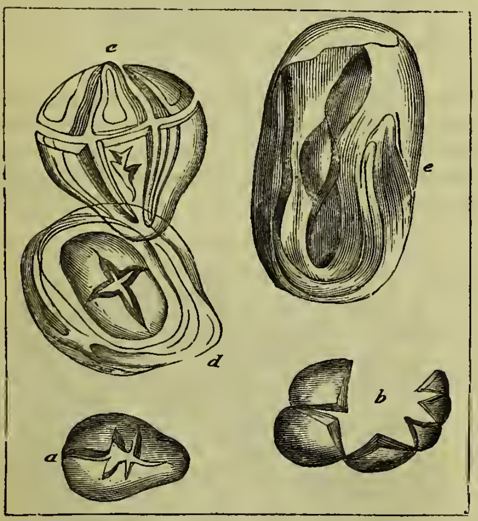
Fig 537.



Case 1. Case 2.

corpuscles are large; and even when imperceptible under the usual magnifying powers, they may be rendered visible by submitting the starch to careful desiccation, when the internal matter contracts, and thus causes an enlarged opening, which, sinking into the granule, exhibits the rings or discs usually observed in starch grains abutting against it, as seen in the annexed figure, exhibiting in Case 1 the starch granules with the hilum, and, in Case 2, the same after desiccation. These concentric rings or bands have led to much controversy as to the true organization of the starch corpuscle. It is generally supposed that it is made up of layers superimposed on one another, from the nucleus to the outer wall, and that the bands contracting towards the hilum result from the upper verge of such layers cropping out. Those maintaining this view hold that the matter in each differs neither in its nature nor composition, beyond being a little denser as the outer surface is approached. Those who maintain the opposite opinion assert that the corpuscles are true cells filled with the true amylaceous matter, and that the bands are simple plications of the walls of the cell.

Fig. 538.



When starch is moistened with alcohol of 0·85 specific gravity, and then slightly heated, the spirit evaporates readily, and leaves a slight particle of water on each grain, which, at the increased temperature, is acted upon more or less; and if the grains be placed in an excess of the liquid so as to remove the entire mass, nothing but a thin pellicle remains. Fig. 538 exhibits granules of potato starch thus treated; the granules, *a*, *b*, *c*, show the effect of the action of the drop of water; *d* shows the partial solution of the substance leaving the insoluble portion; and *e*, the swollen insoluble pellicle. According to **Busk**, the best method for exhibiting the starch corpuscle under the microscope is, to saturate it with a concentrated solution of chloride of zinc containing a little free iodine. No change appears from these agents; but as soon as water is added, the grains assume a deep-blue color, and gradually expand, developing at the same time a frill-like plicated margin, which slowly opens out; the plications on the globule may then be seen slowly unfolding, and may be traced in many cases into the rugæ of the frill. Ultimately the granules swell up to twenty or thirty times their original bulk, in which state they appear as flaccid sacs, though no extrusion of matter can be observed during the experiment.

The Editor finds **Reid** argues, from the following endosmotic experiment, that the starch has an exterior covering or cellular membrane coating the inner substance, and that the latter is not organized in successive layers as if a number of sacs were arranged one within the other. He saturated starch granules with glycerin, and placed them while in this state in contact with water, when endosmotic changes followed, the less dense liquid being absorbed. After the absorption the grains were found to have burst in the direction of their axes, the rupture indicating a membrane that had been corrugated by release from unusual tension, whilst the covering of the remaining portion of the granule was visible in distinct longitudinal wrinkles from the hilum downwards. He submits that, were the corpuscle composed of superposed laminæ only, the addition of water in the manner described ought not to rupture it, or if this happened, the fracture would be in the direction of the laminar surfaces and not at right angles to them or their supposed order, as happened in his experiments. He further holds that the bands or lines observed in starch grains are mere plications of the outer membrane, because they entirely disappear on swelling the corpuscles with any liquid.

In direct opposition to this view may be placed the facts already stated of the combined effect of heat and solvents. Thus, if a little potato starch be heated on a metal plate to 360° or 390°, and then examined after treatment with a little water, the several layers will be found swollen, and by adding an aqueous solution of iodine they will be made to appear with considerable distinctness. The question, however, is not yet thoroughly answered, though the mass of evidence is in favor of the view that an outer cuticle surrounds the inclosed matter, from which, as well by the iodine reaction as by its less solubility, such coating differs in many of its properties.

In the annexed woodcut—Fig. 539—*a*, *a′*, *a″*, *c*, *d*, represent granules of starch heated to 320°, 392°, and 410°, as seen in alcohol; *f*, *f*, the same swelled in water after being heated to 320°, showing the hilum opening inwardly; *g*, granules of the same starch submitted to the last-mentioned temperature and afterwards plunged into alcohol, which, on evaporation, left a little water on the external part of the grain, and which dissolved a portion of the exterior matter; *h*, grains of starch heated between 392° and 420° and then put in water, when they swell to such a degree as to exhibit the different folds of their matter in the form of so many layers. These folds are more easily distinguished by adding a little of an aqueous solution of iodine to the liquid, in order to give them a violet tint.

Before passing to the consideration of the chemical properties of starch it may be well to give, in addition to the descriptive references in the preceding drawings, a few additional facts concerning those starches which form articles of commerce.

Fig. 539.

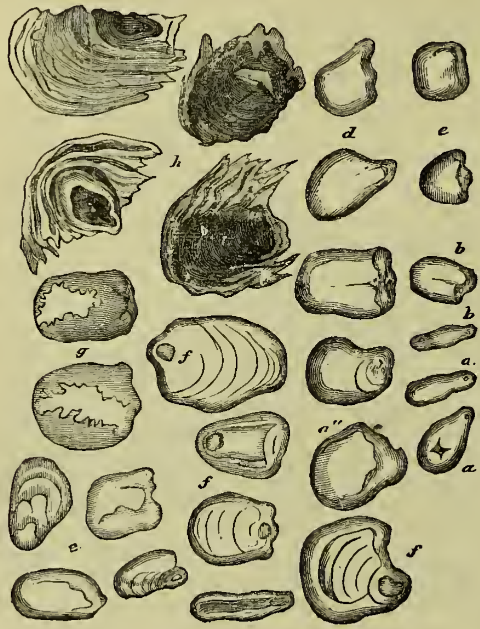
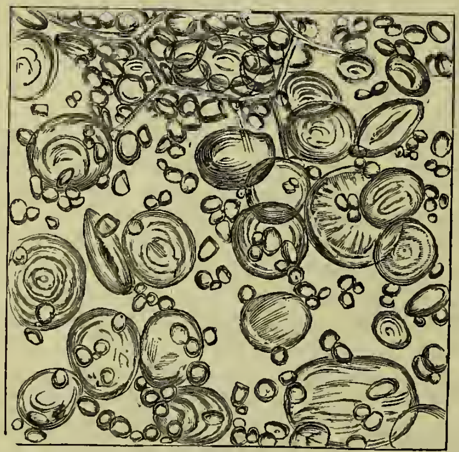


Fig. 540.



Wheat Starch.—The amylaceous corpuscles of wheat differ somewhat among themselves in appearance and size of grain, but generally they are composed of large and small granules, with very few of an intermediate size. The smaller grains are chiefly round, rarely oval, and for the most part provided with the dark central spot or aperture designated the hilum; the large granules are rounded and flattened, so as to give them a lenticular appearance. In most of the grains neither the hilum nor the concentric rings can be distinguished with a magnifying power under four hundred and sixty linear diameters. Viewed edgeways between glass plates, some of the grains seem misshapen, and present the appearance of a longitudinal furrow, occasioned by the partial folding or curling of the grain on itself; this has been erroneously described by Pereira as the hilum. In Fig. 540 are represented the structure and appearances of the starch granules of wheat flour, as also the characters of the cellulose, drawn with the camera lucida, and magnified four hundred and twenty diameters.

Fig. 541.

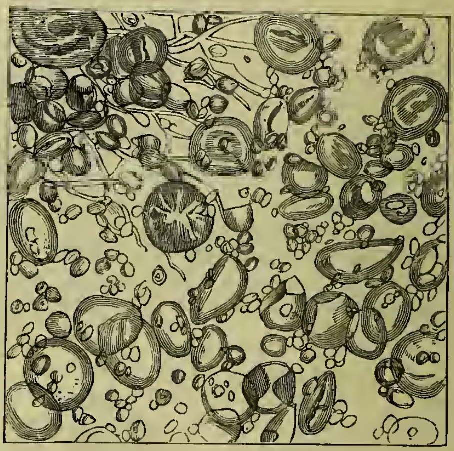
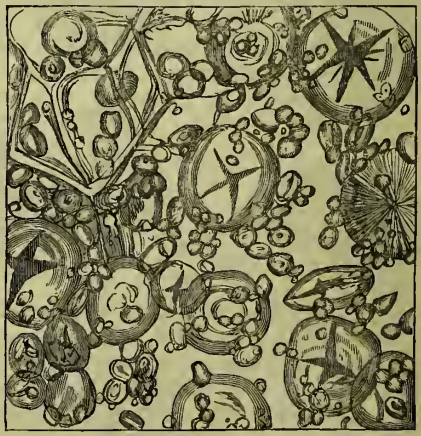


Fig. 542.



Barley Starch—Fig. 541—is somewhat similar to that of wheat, being composed of large and small grains; but the latter are three to four times less than the corresponding ones of wheat starch. This engraving represents the structure and characters of barley starch, together with the cellulose. It is drawn with the camera lucida, and magnified one hundred and forty diameters. A considerable number of the large corpuscles has distinct rings and the furrow already referred to.

Rye Starch.—This variety—Fig. 542—is similar to wheat starch in the form of the granules, but the smaller grains appear to be less than the analogous ones in wheat starch, and the others somewhat larger. In addition to these differences, there is seen on the flattened surfaces of the larger grains of rye starch a three or four, or even five-rayed hilum or spot, which serves at once to distinguish the two varieties. This engraving represents the structure and characters of the starch granules of rye flour. It is drawn with the camera lucida, and magnified four hundred and twenty diameters.

Oat Starch.—The corpuscles of this variety—Fig. 543—are much smaller, but more homogeneous, than those of wheat or barley; and instead of being circular, they have a polygonal outline, and are devoid of visible rings or hila. Many of the granules remain connected, presenting rounded or oval bodies, with a reticulated surface, indicative of their structure. Another well-marked difference is, that the granules of oat starch do not show the usual crosses when viewed with polarized light that the other cereal starches exhibit under the same circumstances. This engraving represents the structure and characters of the starch corpuscles of oat flour, as also of the cellulose. It is drawn with the camera lucida, and magnified four hundred and twenty diameters.

Fig. 543.

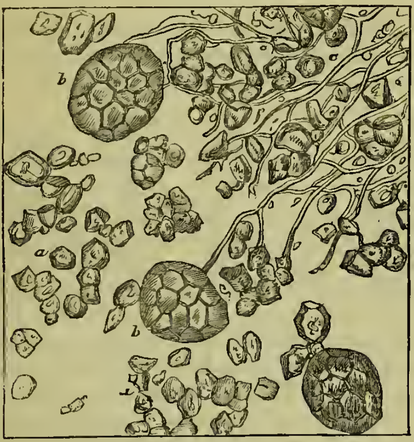
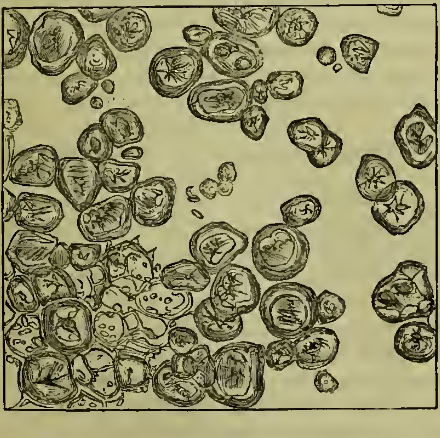


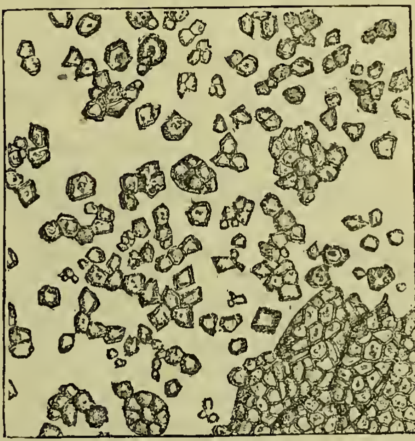
Fig. 544.



Maize or Indian Corn Starch.—This—Fig. 544—resembles in a great measure oat starch in the polygonal outline of its granules, but the corpuscles are much larger, and do not aggregate to form compound bodies, as is the case with oat starch. Under the polariscope maize starch presents well-defined crosses, and, like all the other amylaceous organization of the cerealia, exhibits the central depression of the grains very well marked. This engraving represents the structure and characters of the starch granules of Indian corn flour, including the cellulose, drawn with the camera lucida, and magnified four hundred and twenty diameters.

Rice Starch.—This variety—Fig. 545—representing the starch corpuscles of rice flour, drawn with the camera lucida, and magnified four hundred and twenty diameters—presents the appearance of very small polygonal grains, more angular, however, than that of the oat or maize; it has a well-marked central depression in the grain, the edges of which appear raised. They resemble the starch from the oat grain, by their aggregating together and forming in rounded masses. The preceding figures, representing the starches referred to, are taken from Hassall's *Adulteration of Food.*

Fig 545.



Chemical Properties of Starch.—Viewed chemically, starch may be regarded as a definite compound of water and the true principle of organic formation bearing this name, or *amylin.* If the substance, after extraction from the plant which yields it, be allowed to deposit from the water in which it is held in suspension and then dried by pressing between absorbent media, such as plaster of Paris, till no further loss is sustained, it will be found still to retain forty-five per cent. of its weight of moisture. On exposing this product to moist air at a temperature of 68°, the weight of water will ultimately be reduced to thirty-five per cent. At this degree of desiccation the starch appears of snow-white brilliancy, possessing remarkable cohesive properties, so much so as to allow its being readily pressed into plates possessing a considerable degree of tenacity, and capable of receiving an impression from hard bodies without, however, yielding any moisture to an envelope of bibulous or other paper in which such plates may be inclosed. It is impossible to sift it whilst in this state, and when projected upon metal plates, heated to 300°, the particles agglutinate into compact masses. This property is turned to account in the manufacture of tapioca, sago, and the compounds sold as patent soluble starches, from ordinary fecula or wheat starch.

When the starch which has been desiccated in moist air for several days, is exposed to the circulation of a dry atmosphere, it parts with a further quantity of water, which reduces the per centage of that ingredient to eighteen, and in this state it possesses a very slight adhesive property, but not to such an extent as would prevent it from passing through the meshes of a fine sieve; neither does it swell up or agglutinate as before. Thus dried, it constitutes the ordinary commercial starch. Air-dried fecula of this nature loses a further quantity of moisture when kept in a vacuum at a temperature of 60°, so as to leave only fifteen per cent. combined; and if the heat be sustained at 260° the moisture is reduced to a minimum, or eight and a half per cent. Starch so dried constitutes a monohydrate of amylin or of the true starch principle, from which mere desiccation cannot remove more water without altering or destroying the order of combination of the elements entering into its composition. It is only by combining the matter of starch with metallic bases, such as lead or baryta, that it can be obtained in a perfectly dehydrated state, in which it exhibits upon analysis the following composition, corresponding with the formula $C_{12} H_9 O_9$:—

		At. Weight.	Centesimally.
12 Eqs. of Carbon	= 12 × 6 =	72	47·059
9 ,, Hydrogen	= 9 × 1 =	9	5·883
9 ,, Oxygen	= 9 × 8 =	72	47·058
		153	100·000

By tabulating the results above referred to, the relation between the amylaceous matter and the combined water will be more easily comprehended :—

Condition of Starch.	Formula.	Atomic weight of Starch.	Per centage of HO in thoroughly dried Starch.	Per centage of monohydrate of Starch.
Anhydrous amylin,	$C_{12} H_9 O_9$,	.... 153	0	0
Starch dried at 212° to 280° *in vacuo*,	$C_{12} H_9 O_9$ HO,	.... 162	0	100
Starch dried at 60° *in vacuo*,	$C_{12} H_9 O_9$ HO, 2 aq.	.... 180	10	90·0
Starch dried at 68°, in air containing 0·6 per cent. of moisture,	$C_{12} H_9 O_9$ HO, 4 aq.	.... 198	18·18	81·82
Starch dried in air saturated with moisture,	$C_{12} H_9 O_9$ HO, 10 aq.	.... 252	35·71	64·39
Starch thoroughly drained by absorbents,	$C_{12} H_9 C_9$ HO, 15 aq.	.... 297	45·45	54·55

When subjected to a heat ranging from 395° to 410°, starch is readily converted into dextrin, but some kinds are more easily acted upon in this way than others. If a certain amount of water be contained in the starch, the heat necessary for its transformation is not so great. Thus, when starch dried in a vacuum at 260° is subjected to a temperature of 320° in an oil bath, it does not suffer much change, and retains its property of insolubility in cold water; but when the temperature is raised to 395°, and sustained at this degree for half an hour, the starch becomes altered to an amber color, without, however, giving out much water, and the chief part is dissolved by cold water. It is different with fecula containing four equivalents of water, which, if suddenly brought to 320° to prevent the evaporation of the moisture, passes at this degree into dextrin, so that the effect is in all things nearly the same as if the substance were quickly heated in the air to 395° or 410°. According to JACQUELIN, the changes that follow an increase of temperature applied to starch merely air-dried are these :—From 212° to 284° the hilum is more and more developed, appearing in the end like a large rent or tear; at 320° the granules lose their ordinary form; at 338° the inclosed starchy matter becomes soft and slightly colored; at 356° it turns black, and is soluble; and at 372° to 395° the walls of the grains burst asunder.

Such are the changes which heat alone effects upon starch; they are somewhat different from those that are produced by other agents.

Potato starch or fecula suspended in twelve to fifteen times its weight of water suffers no change, not even when the temperature is raised to 131°, with the exception of a slight increase of the younger or more tender grains; at 135°, however, the corpuscles perceptibly swell, and continue to do so as the heat advances; at 162° the increase of the granules becomes more evident, and the liquid assumes more or less consistency, which goes on increasing up to 212°, when it forms a paste of greater or less thickness. If the proportion of the fecula and water be as one to a hundred and the mixture be boiled, the white color of the corpuscles disappears and the whole presents a perfect solution, so much so as to traverse a compact filter; yet a finer filtering medium can separate the starch so as to make it appear that, instead of being *dissolved* in the liquid, the corpuscles were only largely distended and diaphanous. PAYEN, by immersing the bulb of a hyacinth in such a filtered solution, succeeded in separating the apparently dissolved starch; for there appeared, as the rootlets absorbed the water, particles of starch adhering to them, which were turned blue by iodine, whilst a section of the roots of the bulb gave no indication with this test of the presence of amylaceous matter. Hence it is evident that the fine capillaries of the plant, being too small to permit the passage of the particles of starch, caused their accumulation on the surface—a circumstance which, it may be supposed, would not occur if the starch were perfectly dissolved. Not only is the starch separable from its apparent solution by the means just mentioned, but it is precipitated by cold even when the quantity of water is more than double that mentioned in the last experiment. By submitting starch paste made with fifteen parts of water and one of starch at 212°, to cold sufficient to freeze it, and then allowing it to thaw, a contraction of the paste takes place, and it parts with a portion of its water. By repeating the operation, the starch, which was apparently soluble in water whilst in the form of paste, becomes quite insoluble, and precipitates from the liquid in flakes. Advantage is taken of this property to obtain a felt-like substance suitable for certain kinds of cartridges, and for other purposes to which paper is inapplicable. The paste, after being cooled below zero, is then heated slightly above the freezing point and submitted to pressure, when most of the water is expelled and a dense felt-like matter remains, applicable for the above uses. Even when the quantity of water in which the starch is boiled is two or three hundred times greater than the weight of the starch, it is found that by repeatedly freezing and liquifying, the menstruum and the starch separate in flakes. From all these circumstances it appears doubtful whether starch is entirely soluble in hot water.

Solutions of the fixed alkalies have the effect of swelling the corpuscles of starch, and causing it to form a paste even without the aid of heat. Mixed with an alkaline solution containing from one and a half to two per cent. of alkali, the starch granules appear to swell, when viewed under the microscope, to the extent of seventy-five times their original bulk. By previously drying the starch *in vacuo* till it becomes a monohydrate, the absorbent qualities seem to be considerably increased, for when such fecula is treated with a liquid containing only one per cent. of alkali or less, the enlargement is so great as to rupture the cell walls of the grains, and cause the starchy substance or amylin to protrude and become diffused in the liquid.

When the quantity of alkaline water is not in too great abundance, it converts the starch into a semi-transparent paste, in the same manner as water. It would appear that a salt of the alkali is produced in this operation, in which the starch forms the radical, and from which the insoluble amylates of the alkaline earths or metallic bases may be obtained by simple double decomposition, upon the addition of a neutral soluble salt of those bases. The decompositions in these cases are so complete that, when an equivalent of the precipitant is employed, the filtrate from the precipitate does not, upon the addition of iodine, give the slightest indication of the presence of starch; the iodine will not give the usual reaction of starch with the precipitates till after their decomposition with a weak acid, such as acetic.

From the analysis of the amylates of lime, baryta, lead, and silver, the composition of the true matter of starch, as previously stated, has been deduced.

Sulphuric, hydrochloric, and nitric acids in a diluted state have also the power of swelling starch and converting it into a paste. When sulphuric acid is employed, the proportion of acid in the liquid should form at least three per cent. of strong acid. If, in addition to the effect of dilute acids, the temperature of the solution in which the starch is held be raised to 212°, several changes follow, the first of which is the production of dextrin, a substance isomeric in composition to the true amylaceous matter that is soluble in cold water, and in its properties analogous to gum; the next change appears to be the formation of glucose or grape sugar, a body which differs from starch merely by two equivalents of water, or rather of oxygen and hydrogen; for these elements are assimilated so that they constitute an integral part of the new compound. Its formula is C_{12}, H_{12}, O_{12}, but as it crystallizes from the liquid it takes two equivalents of water of hydration, in which state it may be represented as $C_{12}\,H_{12}\,O_{12}, 2\,HO$ or $C_{12}\,H_{14}\,O_{14}$. These changes take place to a large extent with starch paste made simply with water by the aid of heat, by mere exposure to the air. Thus one hundred parts of wheat starch made into a paste with twelve hundred of water, and the mixture exposed during thirty-eight days, was found by SAUSSURE to yield—

Sugar,	47
Dextrin,	23
Starch granules,	8
Starch,	4
,, altered,	10
	92

The difference in this instance must be attributed to the change in the composition of the substance. This was shown by taking the same weight of starch, treating it as above, and allowing the same period of exposure; it was then analysed, and the results showed a loss of one fifth, thus:—

Sugar,	50
Dextrin,	10
Starch granules,	5
Starch,	4
,, altered,	9
Carbonaceous matter,	0·3
	78·3

A disengagement of carbonic acid accompanies this decomposition when it takes place in the air; if on the contrary, the reaction take place in close vessels, bubbles of hydrogen are evolved from the mixture. In these cases it is probable that the small proportion of gluten in the starch, generating diastase by decomposition, renders the change more active; for it is well known that diastase will convert starch into dextrin and sugar, to the extent of two thousand times its weight.

The starch granules mentioned in the preceding analysis are such as settle down from a solution of starch in water at 300° when the liquid is left to cool; these granules are dissolved in water at 160°, or better when the heat is so high as 212°, and the liquid affords the ordinary reaction with iodine. It appears from the experiments of JACQUELIN that they are permanent, and may be reproduced from their solution in boiling water by simple evaporation in their original form; they are insoluble in cold water, as may be proved by iodine, but when rubbed in a mortar and then diluted with water it is probable that some of the grains are fractured, for on testing the liquid it manifests the presence of starch. The best method for obtaining this permanent form of starch is to digest a mixture of one part of fecula and five of water in a PAPIN'S digester at 300° for two hours, and afterwards to allow the mixture to cool. Should the heat rise to 320° the fecula would be converted chiefly into dextrin, with a little sugar giving a violet color with iodine; on the other hand, if the heat approaches 355° the sugar predominates and very little dextrin is found, so that iodine has no effect upon it.

It has been already mentioned that dilute nitric acid converts starch, equally with dilute sulphuric acid, into dextrin and sugar, after swelling the granules and transforming them into a pasty mass, when the water is not in excess. The result of the action is very different when strong nitric acid is employed. **BRACONNOT** found that fuming nitric acid, specific gravity 1·5, when poured upon starch or fecula, dissolves it, and on the addition of a large quantity of water a substance was precipitated, which, when freed from excess of acid by washing and dried, proved to be highly inflammable and soluble in ether; this is the xyloidin or nitramidin of **PELOUZE**, who found it to be composed of one equivalent of starch with one of nitric acid. With the same acid, and the application of heat, starch is converted into a number of indefinite substances, which ultimately resolve themselves into oxalic acid. This operation, with slight modifications, is followed in the manufacture of the latter article as will be seen by referring to page 637 of this volume.

Hydrochloric acid causes the alterations of starch already mentioned into dextrin and glucose, first forming a jelly, or dissolving the substance according as the quantity of water present is greater or less. Its action is far less energeric, however, than chlorine. The latter element has invariably a decomposing action upon starch, which results in the production of water and carbonic acid. These changes take place even when a solution of hypochlorite of lime—bleaching powder—is put in contact with starch in the cold, but the decomposition is gradual. With an excess of the reagent the transformation is more rapid. Oxalic, tartaric, and other acids have the power of swelling the starch grains, and ultimately converting them into dextrin or glucose. Acetic acid is devoid of this power, and therefore the fecula remains quite unaffected by it. The same inertness is exhibited by ammonia towards this body, and hence the following method by **PAYEN**, for the valuation of vinegar and ammoniacal salts:—He adds about a five-hundredth part of the sample of ammoniacal salt to be tested, of starch to the solution in which the former is contained, and then drops in a standard liquid of caustic-soda till the menstruum indicates the swelling of the granules and the formation of a paste. Previous to this result, the soda displaces the ammonia by combining with its acid; but after the whole of the ammoniacal salt is decomposed, the soda that is added in excess reacts upon the starch, and converts it into a paste. Vinegars unadulterated with mineral acids have no action upon starch, so that when a mixture of the two is boiled, the peculiar reaction of starch and iodine is exhibited unchanged; but if the acid be adulterated with sulphuric or any other mineral acid, the change of the fecula to dextrin and glucose will be proportionate to their quantity, and this alteration will be exhibited by the iodine reaction. The tests, however, considered analytically, are of little value.

The most remarkable property of starch is the combination it forms with iodine, and which is characterized by the well known blue color of the compound.

This reaction, besides being the most sensitive test yet discovered for the mutual detection of starch and iodine, has many other important applications with reference to the changes which the fecula undergoes under the influence of other agents. When a weak solution of iodine is added to starch the blue coloration takes place, but it is so superficial that the granules appear transparent when observed under the microscope. If the quantity of iodine added be greater, the coloration becomes more intense, and to such a degree as to cause the corpuscles to appear black; this blackness and opacity take place when only one two-thousandth of a millimetre in thickness. As the combination proceeds through the entire mass of the granule, the whole appears of a beautiful blue. Between this characteristic blue shade, every gradation of tint is observed till a reddish or orange color manifests itself, according as the starch is disaggregated and changed into dextrin and sugar under the influence of a hot solution acidified by sulphuric acid, or any other body capable of producing the like effect. Thus, a solution of starch in boiling water, when iodine is added immediately, forms a fine blue precipitate; and then by pouring in some sulphuric acid, and maintaining the heat, it gradually changes to various shades of violet, afterwards to wine-red, then to a crimson-red, and finally to an orange-hue. Some of these shades are produced when iodine is added to starch in its progressive stages of development. Young or imperfectly formed starch granules, in which the matter is not properly aggregated, produce with iodine a reddish-fawn color; and as the particles become more united and compact the tint changes through the several stages of violet, in which the blue predominates, till ultimately, as the granules are fully formed, the tint resembles that of indigo.

There are many evidences that the result of this action is a true combination of the starch and iodine. If the compound be kept at 60° *in vacuo*, it retains nearly as much water as the starch itself under the same treatment. When the compound is partially desiccated in the vacuum, and the heat is afterwards raised to about 425° to 430°, a portion of the iodine is expelled, but on cooling the substance again by contact with the air, the shade of color still remains very deep. On adding a little water to the compound, and repeating the experiment under the same circumstances, a further amount of the iodine is displaced though the color is not eliminated. Treated with water at this stage of the experiment, only about two per cent. of the starch is dissolved, and this soluble portion even strikes a violet color upon the addition of a little iodine. Upon examination, many of the granules of the insoluble portion are so highly tinted as to appear black, and these resist the action both of the alkalies and concentrated sulphuric acid in the cold, thus showing that a very strong combination has taken place.

Starch dried at 212° to 266° in a vacuum, and suspended in absolute alcohol, does not unite with iodine dissolved in the same menstruum; but if a little water be added, a violet coloration, which deepens in shade by standing, is immediately produced. From this behavior it might be anticipated that alcohol would abstract iodine from the amylaceous compound. This is to a great extent the fact, for on agitating the blue compound with about twenty times its weight of absolute alcohol, and decanting the liquid after the matter subsides, a portion of the previously combined iodine will be removed; and by a repetition of the process, fresh quantities will be taken up, though less each time, till as much as four-fifths of the combined iodine is separated. When the solvent is employed at the boiling temperature, the decoloration is much more rapid; and if a portion of the substance be viewed under the microscope whilst the reaction is taking place, it will be noticed that the least aggregated of the corpuscles, or in other words, the younger ones yield their iodine first, and turn to a violet and red color. The granules of starch do not lose their distinctive character by combining with iodine, for if the blue iodide, dried thoroughly at 212° in a vacuum, be examined under the microscope in the presence of absolute alcohol, the corpuscles will, as they become decolored, appear intact. If, however, a few drops of water be added to the alcohol employed whilst the substance is under examination, or after it has been dried, several of the grains appear as if burst; the inclosed matter being disseminated in the liquid and colored reddish-violet, the coats of more aggregated matter acquiring by the hydration a shade approaching to a blue.

The blue iodide of starch is decomposed by several agents. Exposed to the light of the sun, it gradually loses its blue color in the presence of water; the effect is more rapid when the menstruum is raised to a temperature of between 86° and 105°. In either case the changes result from the decomposition of water, the hydrogen of which enters into combination with the iodine to produce hydriodic acid, the oxygen forming iodic acid with another portion, so that the mixture becomes colorless. When starch is freshly treated with iodine, the alkalies readily decolorize the compound, owing to an iodide and iodate of the alkali being produced, leaving the starch almost intact in the solution. It is a very curious characteristic of the iodide of starch that, by a change of temperature alone, the blue color may be made to disappear and return several times in succession. If an excess of iodine be poured into the solution of starch the blue iodide will be retained for some time, even at 212°; but when the excess of this element is volatilized by the heat, the compound fades, and even a heat not exceeding 160° will be found capable of reducing the color of the mass completely. On allowing the vessel to cool, however, the blue tint, strangely enough, reappears, and this alternation of color can be repeated by heating the solution, and allowing it to cool again. By degrees, the tint weakens each time the solution is cooled, owing doubtless to the loss of iodine sustained either by expulsion in the form of vapor, or by conversion into hydriodic acid. The blue tint is retained with much greater tenacity when the amount of starch present is greatly in excess of the iodine.

Iodide of starch precipitates very readily from its solutions however dilute; but the coagulation of the matter takes place much more readily in presence of the neutral salts of the alkalies and alkaline earths, and of dilute acids, and even by a reduction of temperature. In all of these conditions the separation is to be attributed to a very marked contraction which the iodine by its union causes in the corpuscles of starch.

It has been stated that water at a high temperature, acid, and alkaline solution have the power of swelling the granules of starch to such an extent as to render them apparently soluble when the volume of water is very large, or to produce a semitransparent jelly, when its quantity does not exceed a certain limit. In the latter case the increase in the granules is greater than the volume of the liquid in which they are held; and, consequently, instead of moving freely as in a solution, the swollen grains are compressed and ramify into one another till the whole becomes as it were soldered—at which stage the mass appears a jelly. When iodine is added to such a mass a reverse change succeeds; and the contraction of the grains enables the compound to precipitate readily, so that, in a short time, the blue iodide will be retained on a filter from the liquid portion. In a very dilute solution of starch the precipitation of the iodide is not so rapid as in menstrua of greater density. Congelation, in such cases, causes the blue compound to form in flocculi in the liquid; and in time they settle to the bottom, leaving the rest of the liquid colorless. Cold has an analogous effect upon fecula which has been distributed in a large quantity of water, and subjected to a temperature of 212°; for, by repeated freezings and solutions of the frozen mass, by successive applications of cold and heat, the starch grains which before had seemed as if dissolved, owing to their great extension, now appear in flocks in the liquid, and can be separated from the latter by simple filtration. In both cases a considerable amount of contraction takes place, to which the separation of the starch, in one instance, and of its iodide in the other, is to be attributed. One equivalent of iodine can fully saturate seven of starch in producing the blue iodide; the ratio of combination between them is therefore as seven to ninety-two by weight, and by volume as one to twelve.

Tannic acid seems to form combinations with solutions of starch, giving a greyish-white flaky precipitate, which becomes transparent in the heat, but reappears in the usual form as the liquid cools. This acid decolors the blue iodide of starch, and when present in sufficient quantity it prevents the entire decomposition of fecula by means of diastase. The reaction contributes in part to the formation of artificial leather on CLAUSSEN's principle, as already detailed in this work.

Amount of Starch contained in different substances.—The quantity of starch in different grains and bulbous roots yielding this substance, varies considerably, both in the per centage, amount, and gross total yield per acre; and these two circumstances must be taken into consideration by the manufacturer in selecting one in preference to another of the many sources whence the starch is extracted. Thus while the potato affords centesimally only from fifteen to sixteen parts of starch, wheat affords as much as sixty per cent.; still the total amount per acre is in favor of the potato in the ratio of 2400 to 996; the produce being estimated at six tons in the first instance, and sixteen hundredweight in the latter.

Different varieties of the same species of grain likewise exhibit a marked difference in the amount of starch, as appears from the following table :—

AMOUNT OF STARCH IN DIFFERENT KINDS OF WHEAT DRIED AT 212°.

	Per cent.
Talavera wheat from Hohenheim,	56·25
Whittington " "	52·45
Sandomierz " "	53·37
Wheat from Giessen,	54·63
Do. from Vienna, No. 1,	65·68
Do. " No. 2,	67·17
Do. " No. 3,	67·45

A difference as remarkable is exhibited in various kinds of potatoes. Thus JOHNSTON found in—

	Per cent.
Red potato from Lanarkshire,	14·08
Small Americans,	17·80
Orkney potatoes,	17·42
Buffs from Forfarshire,	20·71
Kidneys,	14·93
Cups from Argyleshire,	15·41

Mr. HEMING gives the following numbers as the per centage of starch from different varieties of potatoes grown on the same soil in Renfrewshire, namely :—

	Per cent.
Irish blacks,	16·5
Connaught cups,	21·0
White dons,	13·0
Red dons,	10·75

This variation is the more remarkable when considered with reference to the quantity produced per acre :—

	Quantity per acre. Tons.	Amount of starch Tons.
Cups,	13·25	2·9
White dons,	18·50	2·4
Red dons,	14·25	1·5

It may be presumed that much of the discrepancy in the quantity of starch indicated by the foregoing analyses is to be attributed to the age of the tubers; but though the amount of fecula certainly varies at different periods in the growth of the plant, still the experiments that have been made to elucidate this question conclusively demonstrate that even at maturity the quantity of the starch is unequal. The per centage of starch which any given variety yields, depends very much likewise upon the nature of the soil and the weather which has prevailed during harvest, the yield being much less in dry than in wet seasons. Potatoes that have been allowed to remain a considerable time in the ground, or being improperly stored, have become heated and budded, will not be found to contain as much fecula as others of the same kind which have been timely collected and carefully stored; for the sprouting effects the decomposition of a considerable portion of the starch. This is well known in potato-starch factories; for whilst, in the months of October, November, and December, as much as seventeen per cent. is obtained, in January, February, and March, the amount diminishes to fifteen and even twelve per cent.

There is no difficulty in inferring from these facts the advantage gained by extracting the fecula from potatoes during the three months after they have arrived at maturity, rather than at a more advanced season. Analysis of the potato shows that it is composed centesimally of—

Water,		74·00
Fecula,		20·00
Epidermis, cellular tissue, pectose, pectine, pectates of lime, soda, and of potassa,		1·65
Albumen and analogous nitrogenous matters,	1.50	4·35
Asparamide,	0·12	
Fatty matters,	0·10	
Sugar, resin, essential oil—solanine,	1·07	
Citrate of potassa, phosphates of potassa, of lime and magnesia, silica, alumina, oxide of iron, and manganese,	1·56	
		100·00

The following numbers indicate the per centage of starch in the various cereal grains, which can be employed for the manufacture of starch, and in the potato according to KROCKER'S analyses :—

	Cereal grains.	
Wheaten flour,	65·21	66 16
Rye,	61·26	60·56
Oats,	37·93	36·90
Barley,	64·63	64·18
Buckwheat,	43·80	44·45
Buckwheat meal,	65·05	
Indian corn,	65·88	66·80
Indian cornmeal,	77·74	
Rice,	85·78	86·63
Beans,	37·71	37·79
Peas,	38·81	38·70

	Potatoes.	
	I.	II.
Blue potatoes,	23·20	22·80
White potatoes,	16·14	17·98
" "	16·48	16·09

The potato has long been resorted to for the preparation of the cheaper kinds of starch; but, in addition to this source and wheat, from which the finer kinds are made, other matters—such as rice, maize, and barley—are employed in the manufacture. Wheat and other cerealia having been first employed, claim precedence in describing the process on the large scale, notwithstanding that at present these materials are not so generally resorted to as in former times, unless when to some extent damaged, and, therefore, not so well adapted for human food.

MANUFACTURE OF STARCH.—In the manufacture of starch from the cerealia two methods are followed, which may be distinguished as the fermentative or old process, and the chemico-mechanical, or modern and improved method. That the improvements introduced of late years in the manner of making starch possess a decided advantage over the old system, cannot for an instant be doubted, and yet in many factories the old process by fermentation is still followed; a method both noxious and wasteful. By this process, the wheat is first steeped till softened, and then coarsely ground in a malt mill, or crushed between rollers; the crushed mass is made into a thickish creamlike consistence with water, generally the acid water from a previous operation, and allowed to remain in vats or tuns for a period varying with the temperature of the weather from ten to thirty days. The effect of this prolonged steeping is to disintegrate the starch from the glutinous envelope in which it is contained in the grain; an effect produced by the gluten being partly decomposed by fermentation, partly dissolved by the acids formed in the course of the operation, and partly by its property of becoming partially soluble on entering upon the putrefactive change. At first any sugar in the grain, or dextrin produced in the first stages of the process, is dissolved in the water, accompanied by a slight alteration of a portion of the gluten, whereby diastase is formed in more or less quantities; this sugar and dextrin are converted into alcohol and carbonic acid, and by prolonging the operation the spirit is changed to acetic acid. To equalize the action it is necessary to agitate the mass once or twice a day, and likewise to beat into it those portions which the escape of carbonic acid during fermentation may bring to the surface. After a few days the glutinous portion of the grain begins to undergo the putrefactive change more or less rapidly, and this proceeds till it is considered sufficiently advanced to allow the starch corpuscles to be separated in a state of comparative purity. By such changes, ammonia, sulphide of hydrogen, and other disagreeable products are formed, which renders the operation noxious, and often a most offensive nuisance. After the fermentation is supposed to be completed, any excess of water that may happen to be in the fermenting tun is drawn off, and the magma or thin pulpy mass is filled into bags of stout canvas, or other material, the mouths of which are afterwards well secured; they are then placed in water, and trodden upon till the water is quite loaded with starch, when it is drawn off, and its place supplied by fresh liquid; the treading is then repeated till the solution again becomes quite creamy with starch, and this, in like manner, is let off as before. Three or four such washings exhaust the bags of the starch, leaving only the husk of the grain and the altered albuminous matter, which is almost useless. The starchy liquids are made to pass through hair-cloth or wire sieves in their course to the settlers, to deprive them of any portion of husk or fragments of glutinous matter, after which they are allowed to repose in the settlers for several days; the starch sinks and forms a cake of solid matter on the bottom, whilst the more glutinous portion afterwards constitutes a deposit of a brownish color above it. Frequently, in order to delay the deposition of the glutinous matter, very light and finely-divided fibrous matters are introduced, and agitated with the liquor; the glutinous particles by attaching themselves to the fibres of the extraneous substance employed, are retained in the water a much longer time than the starch, so that the under layer of the deposit is almost in a state of purity whilst the gluten and fibre settle down upon it. After drawing off the clear water by a siphon, the impurity on the top of the deposit is separated and set aside to be washed with the next batch; the underlying portion is stirred up with fresh water, and purified by settling and decantation; this operation being repeated twice, thrice, or oftener if necessary. When the starch is sufficiently white, it is put to drain into small boxes, the sides of which are lined with flannel; or it is dug out in lumps from the bottom of the depositing vessel, and placed upon blocks of plaster of Paris, which absorb the moisture, and thereby cause the starch to harden. The deposit in the drainer boxes is similarly desiccated before it is sent to the drying-room.

Bran, and other refuse matters of the wheat, *et cetera*, are generally mixed with the grain in these operations, and increase the amount of the product.

When the gluten is of such a nature as to agglutinate easily, it can be separated by careful manipulation, but not so, without additional labor, when it disintegrates and passes off with the starch into the water. The extraction of starch from the cereals and leguminous seeds is now much simplified by the aid of chemical substances, and consequently the older system is but rarely practised. The length of time which it required, the labor involved in the process, the loss of starch occasioned by its transformation into dextrin and sugar, and finally, the disagreeable and unhealthy effluvia which were evolved, all concurred to render the old process far inferior in every respect to the modern one. In fact the new process introduced by MARTIN offers so many advantages that one might expect it to be universally adopted by the manufacturers of starch from wheat or flour; yet the old system is still practised in a number of factories, the conductors of which allege that the product obtained from the fermentative process has a better color than that prepared by the chemico-mechanical system.

In MARTIN'S process flour is employed in preference to wheat grain or the same coarsely crushed. It is made into a stiff dough with water, and allowed to remain in that state till every part becomes thoroughly saturated with moisture. A mechanical kneader may be employed with advantage to effect this part of the work. The time allowed for the water to permeate the mass varies from half an hour in summer to two hours in the winter season. The inventor employs a trough covered with a wire-gauze sieve, No. 120, to which a pipe and tap supplies a constant stream of water for washing the dough, the water being thrown upon the mass from a rose of forty minute apertures. The workman takes a mass of dough, averaging ten pounds, and placing it under the small jets of water, kneads it on the sieve till the water ceases to flow off milky, using at first only a gentle pressure, which is increased towards the end of the operation. By this careful working, the gluten, which at first is finely divided in the dough, is made to agglutinate into a pasty elastic mass, which becomes more consistent in proportion as the starch is removed, till ultimately nearly pure gluten remains. Another mass of the dough is then operated upon in the same manner, the gluten being each time separated and removed. In this way almost the whole of the gluten is disengaged from the starch. To remove the particles of gluten which accidentally pass through the sieve, the amylaceous washings are allowed to remain for twenty-four hours at a temperature of 70° or thereabout, together with the scum which formed upon the produce of a preceding washing, with the view of inducing fermentation, and thus altering the small portions of gluten still retained. The purification of the product is effected in the ordinary way by successive washings and decantations, taking the precaution, however, to draw off the liquor when the dense portion has subsided, and before it becomes contaminated with the lighter particles held in suspension by the glutinous matter. On allowing these washings to settle for three or four days the suspended starch falls, and is recovered after the liquor is drawn off, drained in flannel-coated boxes, and finished on plaster and the drying stove. It constitutes about ten per cent. of the starch, and, although unfit for fine white goods, it forms a very good paste for colored stuffs, dressing, and the like.

MARTIN'S process is being daily more extended, especially in Germany, with decided advantage over the old system, not only in respect to the gluten which is extracted in the fresh state, and which constitutes a fourth of the weight of the flour, but likewise as regards the starch itself; for from average wheat flour as much as fifty per cent. is obtained, whereas on the old method not more than forty per cent. could be recovered. The cause of this loss is to be found in the change which the glutinous fermentation produces on the starch, and by which it is converted first into dextrin and then through the successive stages into glucose, alcohol, and acetic acid. These changes take place more rapidly in hot weather. By the new process, the gluten separated from the starch forms the basis of another profitable business, namely, the preparation of articles of food, such as macaroni, vermicelli, semolá, and such like; or it may be compounded with other articles, such as flour or potato meal, and made into a wholesome and substantial bread. In summer the gluten separated from the starch retains its freshness fully twenty-four hours; but after this it begins to lose its tenacity, enters into partial solution, and then decomposes; in the winter season it may be retained for two days without injury.

At first it was proposed to utilize the gluten by mixing it with potatoes or inferior flour, and making the compound into bread; but subsequently it was found preferable to mix it with boiled potatoes, in consequence of the insipidity of the compounds with potato starch. The manufacture of vermicelli and macaroni did not at first succeed, in consequence of the proneness of the gluten to decomposition; but this obstacle has now been overcome, and the gluten is made into a highly nutritious and palatable food, for which purpose the patent process of VERON of Vienna is the most applicable. In this method the gluten, after the separation of the starch, is mixed with twice its weight of best flour, and placed in a machine consisting of two concentric cylinders, the inner one of which is furnished with projecting pins, and is made to revolve much more quickly than the outer; the glutinous substance is thereby divided into a mass of elongated grains, which are placed upon trays and dried in the hot-air compartment along with the starch for the space of one and a half to two hours. The whole is then sifted to separate the finer from the coarser particles, and the latter is ground in a mill and resifted. The very rich nitrogenous compound thus prepared offers advantages over macaroni and semolá, owing to the readiness with which it may be prepared into food.

Such are the main features of the process followed in manufacturing starch from wheat, grain, or flour; the details of the manufacture will be more fully given when treating of potato starch or fecula. At present it may be remarked, however, that the different qualities of starch to be met with in the market are simply the successive deposits, or the portions which subside in succession in the tuns or vats within a given period. It may be likewise stated that, with the view of giving a purer whiteness to the product, it is submitted, either in vats or in close chambers, to the action of chlorine or of sulphurous acid, either dissolved in water or as gases. By a slight elevation of the temperature in the primary stages of the hot-air desiccation, the starch undergoes a change which causes it to dissolve in water at a lower heat than it otherwise would; the product so heated bears the name of *soluble* starch.

STARCH FROM POTATOES.—For a long time the manufacture of starch or fecula from potatoes has been rapidly extending in France, and has now assumed so much importance that it ranks, in money value, next to beet-root sugar. In England the practice is not so general, and its development has been much checked by the potato disease. It has been already shown that this esculent yields a large quantity of starch, and the product so obtained possesses all the qualities adapted for ordinary application in calico printing, *et cetera;* it is also extensively mixed with farina, for increasing its whiteness; it is employed in the confection of vermicelli, semolá, tapioca, polenta, and a number of other alimentary substances, distinguished by various designations; also in the formation of dextrin or artificial gum, grape sugar, sirups, molasses, wine, beer, alcohol, vinegar, and several other uses.

In large potato-starch factories it is necessary to have considerable storage room for retaining the tubers during the most part of the year; and care must be taken to obviate, as far as possible, the conditions under which the starch in the potato is liable to undergo alteration. Thus all affected or diseased potatoes should be carefully removed from those which are sound, and the latter ought to be kept in a dry atmosphere, and at a temperature as low as possible. Dry cellars or pits formed in the ordinary way, if dry at the base, and securely covered with straw and earth, serve for some time; but a well-ventilated barn or shed with grated floorings, one over another, whereon the potatoes may be laid to the depth of two feet, or thereabouts, will answer the end much better. In any case it is necessary that, during the spring and first of the summer months, the potatoes be turned frequently, so that any shoots which may be forming be broken, and the progress of decomposition in the substance of the bulbs be thereby intercepted.

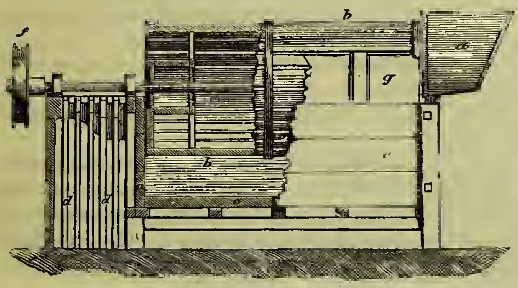
Few operations are simpler than the extraction of fecula from potatoes; nothing further is necessary than the rupture of its cellular matter either by rasping or grating, so as to liberate the starch granules, and the washing of this pulp upon a metallic plate or stage by a stream of water, such washings being afterwards passed through a fine sieve. The solid matter of the potato is thus left on the plate, whilst the starch is carried off in the water, and separated from any grosser impurities by the straining or sifting.

Finally, the fecula is purified by washing and decantation, *et cetera.* Simple as this process may appear, it is divided into several distinct operations, which will be described in the order in which they are carried on in the French and other manufactories of fecula.

Steeping the Potatoes.—This operation, which is preliminary to the washing, and has in view the softening of the clay and other adhering gross matter, that they may be more easily removed, is performed in a large trough or vat, filled with water, in which the potatoes are allowed to steep during six to twelve hours, according to the quantity of the impurities.

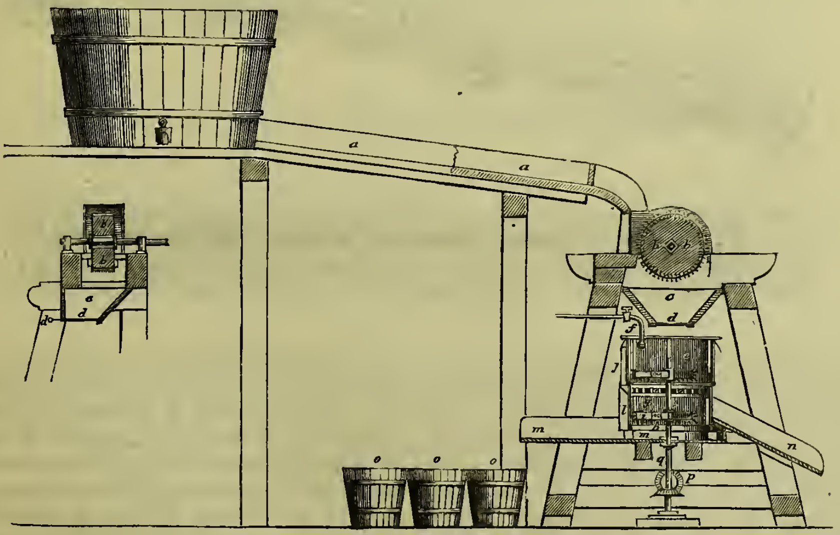
The Washing.—The next operation is the washing which is effected by mechanical means and the aid of steam. Fig. 546, represents an elevated view of the machine employed, which consists of a hollow cylinder, *b b*, constructed of laths of wood or iron, laid longitudinally from one end to the other, the distance between each being such as to permit of the escape of the dirt, stones, *et cetera*, whilst the tubers are retained. The cylinder is charged from a hopper, *a*, at one end, and being slightly inclined, the washed potatoes are discharged at the opposite end, down the inclined plane, *d d*. About a third of the cylinder is immersed in the water of the trough, *c c*, wherein it revolves, and from the sides of which spring the boards, *g g*, slanting to the upper part of the cylinder, and intended to prevent the splashing of the water during the movement of the machine. This cylinder is worked by a band passing over the wheel, *f*, at the end of the axis, and a drum-head of another shaft in connection with the main shaft of the engine. The inclined plane upon which the potatoes fall when thrown out conducts them to the rasping machine.

Fig. 546



Rasping or Grating.—The object of the rasping is to reduce the tubers to a pulp, by which the cells containing the fecula are ruptured; and the finer this rasping is effected, the more freedom will the starch have in escaping. In some instances, this operation is performed by means of a hand-machine; but generally, the larger factories adopt a machine by which the rasping and the washing of the pulp are effected consecutively. The circular drum bearing the rasp is turned by a winch handle, and while revolving meets the tubers in the hopper, reducing them to a pulp which falls by the aid of inclined boards into a vessel moving on wheels, and on which it is carried to the washing stage. A small stream of water is conducted on the upper surface of the rasp, with the view of keeping it clean from accumulation of pulp. The rasp itself is made of plate iron, punched from the reverse side with an angular, semicircular, or round tool on a yielding support, which allows the angular fractures of the iron on the under side to remain unflattened. With a machine of this kind, from two and a half to three tons of potatoes can be turned into pulp by three men in twelve hours. The other kind of machine is shown in Fig. 547, in connection with a portion of the washing apparatus. It consists of a cylinder about twenty inches diameter, and the same in length, mounted upon an axis. The cylinder is armed with steel-saw plates, placed at the distance of little more than three-fourths of an inch apart; the teeth of these saws, which are very small and regular, and placed

Fig. 547.

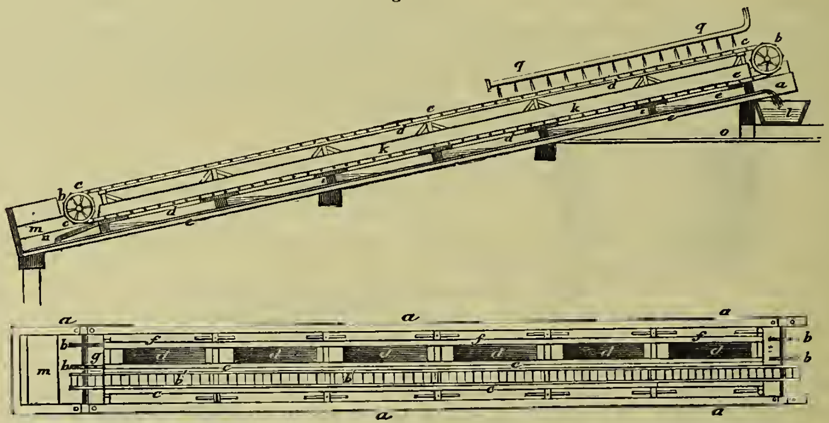


parallel to the cylinder, being held fast by iron clasps, project about four-fifths of an inch from the periphery of the drum, and the whole is turned with a speed of six to nine hundred revolutions per minute. Such a machine, making on an average eight hundred revolutions per minute, reduces to a pulp from sixteen to eighteen hectolitres of potatoes per hour, or forty-two and a half to forty-eight bushels.

In the preceding figure, the rasping drum is shown at *b b*; the inclined plane conveying the potatoes from the washing machine is indicated by *a a*, and the hopper into which the pulp falls by *c*, whence it is dropped into the washing machine by the trap-door *d*. The washing apparatus for exhausting the pulp, is that introduced by M. Saint Etienne; it consists of a cylinder of wire gauze, *e*, fastened upon wooden or iron rings for support, and divided into two compartments, *j*, *l*, each provided with a wirecloth bottom, the lower finer than the upper one. The whole is inclosed in a sheet-iron or wooden covering, which prevents the escape of starchy waters from it when working. In the middle of the cylinder is a shaft, *q*, carrying arms furnished with brushes, *i*, *i*, which sweep the bottom disc of each compartment, and force out the fecula into a trough as the shaft is turned by the gearing of another one, *p*, acting upon a wheel appended to it at its base By the very rapid revolution of the brushes and agitators in the drum, aided by the stream of water projected from the rosed-pipe, *f*, the pulp is speedily washed, the fecula passing out at the sides and middle disc, *g g*, whilst the coarser pulp is thrown out by lateral openings, and is removed from the outer case by a door into the canal, *n*. The finer portions of the pulp, which pass through the upper part of the machine, are separated in the lower one; the granules of fecula falling through the fine meshes of the wire swept by the brushes into a trough, *m*, leading to the vats, *o*, *o*, *o*, where the starch is permitted to deposit, whilst the fibrous matter is ejected by an aperture at the side, and removed through a door in the case to the canal, *n*. In this form of machine there are several imperfections, which are obviated by a modification introduced by Lainé. The principal defects are, that the working is not continuous, the machine having to be stopped at intervals to remove the exhausted residue; that only comparatively small portions can be operated upon at once; and lastly, that the residue is not thoroughly divested of its fecula.

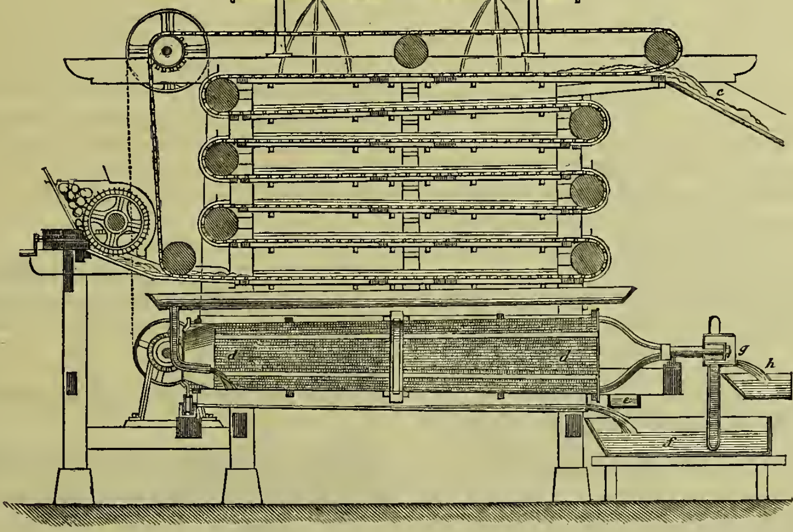
In the machine, improved by Lainé, and further perfected by Dailly, the wire sieves are retained, but the washing space is considerably extended and prolonged, though the quantity of pulp exhausted in a given time is increased. This is done by means of an inclined sieve, represented in plan and section—Fig. 548; a long inclined plane is constructed of planks, and this plane is converted into a kind of trough, by side planks, *a a*, secured in their places by cross planks, *i i*, and bolts, which fasten the latter to the base, *e e e*, of the plane. At each end are pullies, *b b*, the crowns of which are notched in eight places, and into which the bars, *b′ b′*, connecting the endless Vaucanson chain, *c c c c*, are caught and carried forward as the pulleys turn. Motion is given to these by connecting the axle of the lower one with the shaft of a steam-engine, water-wheel, or other motive power. Each of the eight divisions of the base of the inclined shallow sluice formed by the cross bars *i i i*, is covered with a wire gauze, *d d*, increasing in fineness from the lower to the top one; and upon this finely-perforated surface the pulp to be washed is conveyed by the bars, *b′ b′*, connecting both links of the chain as it travels from the lower to the upper end, in the slides at the sides and overhead, as seen at *f f f* in the figure. The chain and grooved slides on which it moves on its return overhead are supported by upright pieces of wood, bearing horizontal pieces, *g g*, on which the part *f f f* rests. From the rasping cylinder, or *cylinder devorateur*, as it is called, the pulp is conducted into the trough, *m*; and being diluted with the water employed to keep the cylinder clean, it overflows the inclined board, *n*, and so comes within reach of the cross-bars of the Vaucanson's chain as it travels over the lower

Fig. 548.



pulley, whence it is conveyed over the several compartments of the wire gauze in the inclined plane; but whilst in the act of passing upwards it meets with a stream of water projected from a pipe, *q*, along the upper three divisions of the plane, and which flowing downwards over the several frames, completely exhausts the pulp of all its fecula, leaving nothing but fibrous matter, epidermis, *et cetera*, when it reaches the top and is thrown out into the trough, *l*. From the three upper compartments the water projected upon the mass is conveyed to the lower ones in succession by a series of pipes, not shown in the drawing, connecting the several levels; thus from the lowest part of the highest square, a pipe issuing at the side conveys the liquor to the highest part of the third square; another from the lowest part of the second delivers the starchy liquid of this upon the fourth square, to meet the ascending pulp; the third sends its water to the fifth, and so on to the lowest and first division, whence it issues into the canal, *r*, leading to the settlers. Two sieves and two travelling chains are generally worked upon the plane, provisions for which are shown in the drawing, the one movement working both. To avoid the inconvenience of the great length to which these planes extend on LAINÉ's plan, and also in DAILLY's, M. SAINT ETIENNE places the sieves one above another, and carries the endless chain over each, as shown in the drawing, by means of pulleys at the ends, the pulp being secured by a flange passing over the pulley and chain in each case. The pulp is delivered at once from the grater or *devorateur* to the chain carriage, and carried upwards till it is discharged at the top into the sluice exhausted of its starch. The disposition referred to is shown in Fig. 549, in which the principal parts are similar to those last described. The water entering upon the top of the apparatus, flows from the highest of the compartments of each of the levels to the lowest, and thence upon the highest of that immediately beneath, and so on till it travels over the whole space to the base, where, loaded with the fecula, it collects in a receptacle, whence it flows by a pipe into a circular drum, *d d*, of very fine iron wire, revolving upon a central axis moved by mechanical power. Any pulp still retained is here separated and ejected into a receptacle, *e*, at the lower end, whilst the starch flows with the water through the gauze into the vat, *f*, and thence, by a *denaide* mounted upon the end of the axis of the cylinder, and revolving upon it, it is lifted into a sluice leading to the settlers, which are disposed as represented in Fig. 547.

Fig. 549.



By such a machine as the preceding, it is stated that the pulp from one hundred and sixty hectolitres—four hundred and forty bushels—of potatoes is exhausted in twelve working hours.

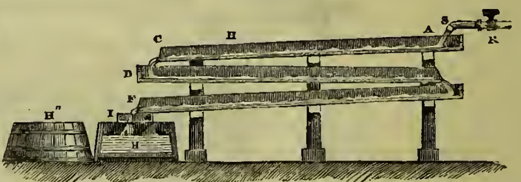
Besides the foregoing, several other inventors have constructed machines in which the advantages of uninterrupted working, combined with complete exhaustion of the pulp within the smallest space, have been the points aimed at, and such advantages are claimed by HUCK, VERNIER, and STOLZ for their respective machines. All, with the exception of SAINT ETIENNE, have recurred to the cylindrical wire-gauze sifter, as being the one which affords the largest extent of surface in the smallest space. HUCK's machine consists of two wire-gauze cylinders, connected by a brass drum; in the cylinders are inclosed brushes and rousers, as usual, and also two drums, one for supplying pulp and water to the upper, and another in the lower for supplying water only. Both the wire-gauze cylinders and the drums move independently of one another and in opposite directions, the brushes and rousers taking the same course as the inner drums. The continued agitation in passing through both the cylinders, together with the action of the rousers, deprives the pulp of the most part of the fecula. The starchy liquid is collected in a cistern beneath, and flows into a third circular sieve in which only brushes revolve, but the wire of which is much finer, so that the last portions of pulp are separated VERNIER employs a combination of three cylindrical sieves moving on the same axle; the pulp arriving at the upper part of the first or smaller cylinder falls into it, and subsequently by the rotation of the entire system, as well as by the inclination at which the cylinders are fixed, it traverses each successively, being always exposed to a stream of water, till the exhausted matter finally issues partially drained from the middle one. The drainings from the sieves collect in a tank below the cylinders, and are thence conducted through another fine cylindrical sieve for depuration before they are run off to the settlers. STOLZ's machine is on the same principle as the preceding, and is said to be very effective, working off not less than four hundred and forty bushels of potatoes in a space of not more than twelve or thirteen feet. Whatever be the form of sieves employed, it is evident that the efficiency of the process depends in a great measure upon the quality of the rasping machine, and the fineness to which it reduces the tubers. On an average, only sixteen to seventeen per cent. of starch is obtained from potatoes really containing from eighteen to twenty or twenty-one per cent.; and therefore from two to four per cent. is left in the residue in consequence of the inefficacy of the *devorateur* to rupture all the cells containing the starch corpuscles. VÖLKER to obviate this, proposed to disintegrate the cells of the potato more completely than is done by the rasping machine, by submitting the pulp to a fermentative process, at a temperature between 68° and 86° in presence of sufficient water, by which the cells are in a short time destroyed, and the whole of the fecula is set free to be removed by a course of sieve washing. Though good in principle, yet the time occupied, and the difficulty of removing the greatly disintegrated cellular substance, offer almost insurmountable obstacles to the adoption of this method.

After the extraction of the starch from the fibrous matter of the pulp, the next operation is the separation of any particles of sand, clay, and other heavy impurities from the fecula. This is done by allowing the liquor as it passes off from the sieve to collect and repose for the space of a few hours, when the supernatant liquid is siphoned off, and the deposit agitated with its own bulk of water; the mixture is then passed over a fine sieve, by which stones, sand, and coarser impurities are removed. Three or four such repetitions with fresh water, using at each successive sifting a finer wire gauze than the preceding, complete the purification. To assist in this part of the work a mechanical agitator is employed in the large fecularies, similar to that shown in Fig. 553, and which may be elevated or lowered at pleasure by a lever handle. When such an arrangement is appended to the sieves the labor of purifying the starch is much diminished, as the various impurities are retained in the intermediate vessels.

PURIFICATION.—The several filtrations and depositions above alluded to being effected, the milky liquor is allowed to flow into large settlers, where it is left to repose for several hours, till the whole matter in suspension falls to the bottom; the clear water is then siphoned off, and the brownish layer on the surface, consisting of fibrous particles, pulp, and other substances lighter than the fecula, scraped off as clean as possible by an iron scraper. This impure starch is agitated with fresh water, and then passed through a very fine brass wire or silk sieve, and allowed to rest for some time, till a further amount of white starch falls, when the same operation is repeated. The deposit left after the removal of the brownish light matter, is known in the French and Belgian works as *gras de fécule.* It is further purified by stirring it with fresh water, passing the mixture through a No. 90 brass-wire sieve, or one of silk cloth, conveying the milky liquid into a vat, allowing it to rest till the starch falls, then decanting and scraping the surface, and finally, if the mass be pure and of sufficient consistence, dividing it into lumps and placing these to dry, either unsupported or in a conical wire case; if it has not acquired this density it is customary to agitate it, and to run the thick semifluid mass into small perforated boxes lined with coarse cloth, such as flannel or calico.

Sometimes the purification of the fecula, deprived of its supernatant brownish deposit, is effected by washing it under a slight stream of water on an inclined table or sluice, twenty to twenty-four feet long by three feet in breadth, and declining one and a half to two inches in its whole length; the lighter matter is carried off by the water, leaving the pure fecula. Figs. 550 and 551 illustrate this arrangement; A, C, represent a portion of the first plane; D the next; and F the third; the three being placed on supports one above another to economize room. The starch being spread upon the first ledge, a stream of water in numerous small jets is delivered upon it by the pipe R; the workman agitates the surface of the layer with a brush, and the slight current carries the lighter particles forward, depositing a portion of the fecula in suspension as it proceeds, till it arrives at F, whence it falls into the canal, I, and thence into the settler, H. The purified starch is then brushed from the plane under a stream of water into the second vessel H′; and by siphoning the liquor from the vessel H into H″, the operation of laying a second batch may be proceeded with. As soon as the fecula has subsided in the tub or vat H′, the water is decanted; the starch is then transferred into boxes of a conical form, perforated

Fig. 550.



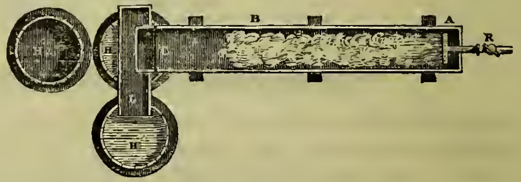


Fig. 551.

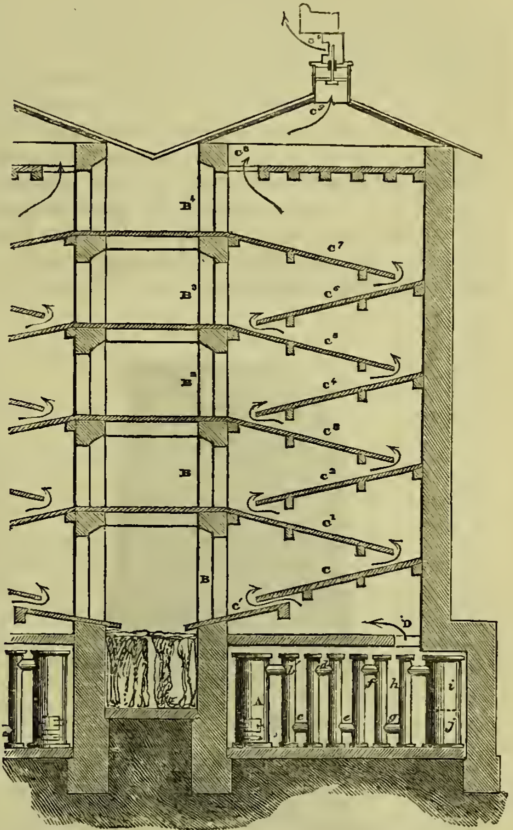
to allow the water to drain away, and covered with cloth and set aside.

DESICCATION.—At this stage another operation, the *drying of the starch*, commences. It may be remarked here, however, that the large quantity of fecula which is converted into grape sugar and dextrin is not dried, but is at once acted upon in a manner which will be described at the end of this article.

During the time that the starch is allowed to drain in the lined boxes, it acquires sufficient hardness to enable it to retain the shape of the box; and as soon as this state is attained, the mould of starch is inverted upon a mass of plaster of Paris, which abstracts a further portion of the retained moisture, thereby rendering the loaf of fecula so solid as to endure being placed upon the stages of the drying-house for further desiccation. In this state the product is known as *green fecula*, and contains fully two-thirds water.

Desiccation in Free Air. — The free-air drying chamber is a large rectangular room, on either side of which are ranged, one above another, a number of horizontal shelves formed of bars of wood placed at a distance of three quarters of an inch to one inch apart, the whole being supported by upright posts, as shown in Fig. 552. A current of air is passed through the gallery by means of venetian ventilators at both sides, which admit of increasing the draught at will without permitting much dust to enter. The loaves of fecula are broken into three or four pieces, and laid on the longitudinal hurdle or bars already mentioned, on which they are permitted to remain during six or eight weeks; they are then taken, and, if necessary, reduced to powder under a wooden roller, and placed in the hot-air stove. In the construction of the latter, it is indispensable to have the arrangements such that the heat may be entirely under control; for if a high temperature were to act upon the starch, the corpuscles would be swelled to bursting, and a number of gummy concretions in proportion to the extent of the change would result. Such a consequence need not be feared after the chief part of the water still retained in the starch—amounting to forty per cent.—has evaporated. Several kinds of drying stoves are used for this purpose; one being a long gallery like the preceding free-air drying chamber, closed with apertures in the front for sliding shelves, on which the starch is placed to pass inwards where the warm air circulates. The heat in these cases is obtained from cast-iron pipes passing round the walls at the base, in which the draught from a fire is conducted to the chimney; and getting thereby warm they heat the air in the interior as it passes through the compartment. Fig. 552 is a sectional view of the drying stove of LACAMBRE and PERSAC, in which the starch is exposed gradually from 60° to 212°, the highest degree of heat to which the fecula is subjected. It consists of a chamber, beneath the ground floor of which a heating apparatus consisting of a stove, A, and a system of iron pipes, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, leading to a chimney, is erected; and the air entering this compartment by lateral apertures passing over the heated surface of these pipes gets warmed and ascends by the opening, D, in the drying chamber, where, following the direction of the arrows, it successively passes over the inclined tables, C, C^{1}, C^{2}, C^{3}, C^{4}, to C^{7}, and thence to the outlets—C^{9} and C^{10}—at the top. The starch passes in an opposite direction, being introduced at the door, B^{4}, at the top upon the plate, C^{7}, and thence it is pushed forward over the plates, C^{6}, C^{5}, C^{4}, C^{3}, by the aid of the working doors, B^{3}, B^{2}, B^{1}, and B, till it arrives dried at C, and falls upon the ledge, C^{1}, into the receiver outside the wall of the chamber.

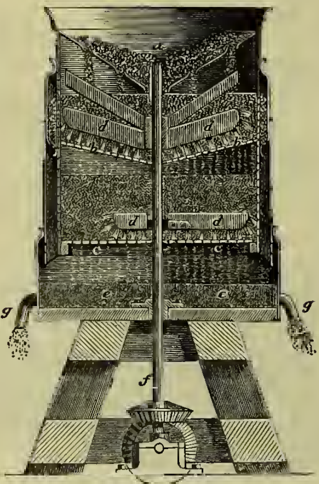
Fig. 552.



Another drying chamber constructed upon the same principle, but self-acting, consists of a chamber and heating apparatus essentially like that last described; but instead of plates inclined one towards another, there are a number of rollers fixed two and two at the same height in the interior, upon which travels an endless band of cloth, and which are sustained in the middle by cross rods of wood. By means of gearing-wheels on the ends of these rollers, the cloth of each pair is moved in an opposite direction to that immediately above it, and the whole are set in motion by the power acting upon the highest roller, *e*, in the chamber. All the gearing-wheels on the axles of these rollers being of the same diameter, they move with the same velocity, so that the moist starch, introduced through the door at the top and spread upon the web, is carried forward from one end of each web to the other, till it reaches the utmost limit of the lowest one. From the disposition of the rollers the fecula falls from one cloth to another alternately at either end, and ultimately into the chamber, the heated air ascending in an opposite direction.

The fecula during the passage through these hot-air chambers loses from eight to fifteen per cent. of moisture, according as it has been more or less dried in the free-air chamber, and is now in the ordinary state for sending into the market, except when, for laundry purposes, it is mixed with a certain amount of coloring matter, such as smalt blue and the like, or sometimes of late with incombustible matters, to secure fine light dresses from being so prone to ignition. Fig. 553 represents an apparatus employed for this purpose; *a* is a conical hopper in which the fecula is put, together with the smalt, indigo, or Prussian blue employed. The mixture passes through numerous holes in this funnel-shaped hopper, and falls upon the first sifter, *b b*, through which it is urged by the revolving brushes, *d*; thence it descends to the second and finer sifter, *c c*, swept, like the other, by brushes, which accelerate the passage of the fecula into the bottom, *e*, of the vessel, and from this it runs by the tubes, *g g*, into sacks or boxes placed for its reception. The brushes are attached to a central shaft, *f*, which is turned by the gearing-wheels in connection with an engine, or other motive power. Sometimes the slight coloration which is given to laundry starch, as sold by grocers generally, is communicated immediately after the first desiccation in the free-air chamber; and the moisture is driven off afterwards in the drying stove.

Fig. 553.



Rice Starch.—Within the last twenty years the extraction of starch from rice has received considerable attention in England; and is now extensively practised. It will be seen from the results stated at page 950, that this grain contains more starch in proportion to its other constituents than any other; the gluten, however, is so minutely divided in it that its separation was impossible by the old system of fermentation, and this accounts for the preference so long given to wheat and flour. By the partial use of chemical agents this difficulty has been overcome, and rice is now extensively employed for the manufacture of starch. Among the several patent processes introduced for this purpose are those of Jones, Berger, Bierley, Rehe, and others, who employ either an alkali or an acid for the solution of the gluten.

Jones directs that the rice be steeped in a solution of caustic potassa or soda, containing two hundred grains of alkali to the gallon, using fifty gallons of such lie to one hundred pounds of rice; the mixture is well stirred, and then allowed to digest for twenty-four hours; after which the lie is siphoned off as much as possible, and the grain is washed with twice as much pure water as the liquor drawn over. The grain is then placed upon a drainer, after which it is crushed or ground between stones or rollers, and the coarse flour sifted in an apparatus furnished with brushes. That which refuses to pass through is returned to the mill with a fresh portion of prepared grain, and this process is repeated until the whole, with the exception of the husk, is made to pass through the sieve. The meal thus obtained is treated with a further quantity of the alkaline liquid, the proportions being one hundred gallons to a hundred pounds of the meal, and the action is quickened by frequent agitation of the mass during twenty-four hours; after which it is allowed to repose seventy hours. During this period there is first a deposit of fibrous matter with a little starch; then the starch falls, the chief portion of the gluten, with some other bodies, being retained in solution by the liquor, which is removed by a siphon without disturbing the separated matter. Double the previous quantity of pure water is now poured on the starch, the whole being well agitated, and allowed to rest for an hour, to permit the heavy substances other than starch to fall to the bottom; this done, the milky liquor containing the chief portion of the pure material is drawn over into another vessel, being passed in its course through wire or cloth sieves. A further quantity of water is used to wash the deposited matter, which, being agitated with the liquor as before, the whole is left to rest; and after the crude impurities have fallen, the starchy menstruum is again drawn off. By repeating these operations as often as may be necessary, the separation of the starch is completed; and the fine silk or brass-wire sieves detain any fragments of husk, so that the substance is well purified. All the successive liquors being added to the first, the whole is stirred and then left to settle for seventy hours; after this time if the whole of the starch has subsided, the clear supernatant liquor is drawn off, the deposit is mixed with the necessary quantity of coloring matter, and then treated in the usual way by boxing, draining, and desiccating.

Berger's process is analogous to that just described; a hundredweight of the rice is steeped during two days, then removed from the water, and after being drained, is crushed or ground to meal, among which as much water is introduced as to give it the consistency of thick cream; in this condition it is passed through a sixty-holed sieve, returning what is too coarse to be further ground. The filtered or sifted mass is now stirred with a solution of seven pounds and a half of carbonate of soda in three and a half gallons of water; and when the whole has been thoroughly blended, it is allowed to rest during four hours, then agitated again, and the operation repeated at equal intervals till the contact has been prolonged to about sixty hours. After this it is suffered to rest eighteen hours, and at the end of that time the lie containing the chief portion of the albumen is drawn off. A second treatment with a similar lie is succeeded by a washing with large quantities of water, and after allowing the heavy particles to fall, the milky liquor is passed through fine sieves, and the starch further purified by the inclined plane, or by repeated washings and depositions.

By another process, likewise patented, BERGER proposed to prepare the starch of rice by fermentation, the chief feature of which is the steeping of the grain in water for successive periods of four to six days, then grinding in the usual way, and repeating the steeping until the entire gluten has been so far altered by fermentation as to be taken up by the several liquors; the starch is afterwards finished by siftings, washings, *et cetera.*

COLEMAN, in 1841, patented the following method of preparing rice starch by fermentation:—The rice is steeped during five or six days, then drained from the water, and ground in the usual way; the meal reduced to a pulp is mixed in the recipient with a quantity of the refuse of wheat, or other fibrous matter, in the proportion of fifteen pounds of the latter to the hundredweight of rice, and a sufficient quantity of water is added to reduce the whole to a homogeneous mass, which is allowed to rest during ten to fifteen days. The patentee states that by this time the starch will have separated, and may be purified in the ordinary way by washing and sifting.

Another mode for preparing rice starch by the agency of acids is thus described:—The substance after being steeped for four days is drained, and then reduced to a pulp in a mill under a stream of water, which carries it off to a reservoir, where it is allowed to settle, and the water is then separated by a siphon or plug-hole in the vessel. The deposit is then agitated with an acid liquor prepared by adding three quarters or one ounce of ordinary hydrochloric acid with two pounds of rice to the gallon, stirring well the whole mass, and leaving it to stand during five days with agitation at intervals of four hours; finally, eighteen hours are allowed for the substance to deposit, after which time the clear liquor is drawn off, and the operation repeated with a second acid liquor three-fourths of the strength of that first used. When the period mentioned for the final deposition of the starchy mass has transpired, the acid liquor is drawn off as before, and the residue washed with large quantities of water, passing it through sieves as usual to separate the husk and other impurities which may still remain, and finally the mass is drained and dried in the ordinary way.

REHE took out another patent for a method for preparing rice starch, the chief feature of which is, that he submits the rice at first to a temperature of 160° to 180° before steeping; and after the matter is levigated, he employs a stronger alkaline lie—four pounds of soda to a hundredweight of rice—for washing the pulp. In the subsequent washings, *et cetera*, the treatment prescribed by the patentee is similar to those already mentioned.

RAINSFORD employs hydraulic pressure in conjunction with alkali to extract the fibrinous matter from the rice before grinding, and finishes the product by further treatment with alkaline-water washings, siftings, and the like; he uses pressure also to expedite the operation of expelling the last portions of water from the finished starch.

MAIZE or INDIAN CORN STARCH.—Of late years maize has been used for the manufacture of starch, and has been found to answer the purpose very well, containing as it does a large per centage of that substance. The principal makers are POLSON and BROWN of Paisley, Scotland, who employ a process patented by the former in 1854. By this method the grain is first steeped either in an alkaline water of the usual strength, or in water only, till thoroughly soaked; it is then levigated in the ordinary way either by rollers or a mill, and the pulp is passed over a sieve, through which the finer portions are forced by revolving brushes, whilst the coarse matter is returned to the mill to be further levigated, and is then sifted again. In this way most of the husk is separated from the flour or starchy portion of the grain, and is economized as cattle food. A stream of water passes in upon the sifting machine, and carries the portion passing through the sieves over an inclined plane, or *run*, the breadth and length of which are proportioned to the work to be performed. In its course the heavier starchy matters subside, and the lighter fibrous substances are carried forward by the stream till they are thrown off. The plane is divided by dams, or pieces of wood laid across it, which intercept the deposited starch, until it accumulates in quantities convenient for removal. Most of the glutinous or fibrinous matter and husk is thus separated, and a starch is obtained which, though not entirely free from nitrogenous and fibrous matter, answers well for ordinary coarse work, having high stiffening powers. It has also been introduced by that firm as an article of diet, and meets with extensive patronage. When a finer kind of starch is to be prepared, the deposit from the plane is treated with an alkaline liquid, by which the gluten is dissolved; and by sifting through a finer texture, washing on the plane, and the other usual manipulations, the starch is obtained perfectly pure.

WATT of Belfast is also patentee of a process for preparing starch from maize, and which in its chief features is similar to the foregoing, with the exception that WATT steeps the grain in repeated changes of water, or in a current, till incipient fermentation takes place, the water being in either case heated between 70° and 140°; after which the matter is drained and ground as usual, with the necessary quantity of water, likewise heated, to reduce it to a creamy consistence. This is then sifted with the aid of brushes, and the coarser portions returned, if necessary, to be again levigated, *et cetera.* The sifted matter is washed and purified either by the inclined plane or in vats, as in the preceding methods.

STARCH FROM MILLET.—A process patented by RICKETT for the extraction of starch from millet, especially from that kind known as *Dari*, embraces the usual series of operations, namely, steeping, grinding, sifting, and treatment with alkalies, alkaline carbonates, or acids, such as hydrochloric or acetic acids, washing and finishing in the manner already detailed.

Starch from Horse-Chestnut.—Hedenus and Flaudin have proposed to extract starch from the horse-chestnut, in which it is stated to be contained to the extent of twenty-five per cent. The chestnuts are steeped in boiling water, then skinned and grated; the pulp well mixed with soda in the proportion of one per cent. of the chestnuts operated upon; and, after a certain time, the starch is obtained by washing the mass in the ordinary way. The alkali, it is said, thoroughly removes the bitter principle of the nut.—*Richardson and Ronalds.*

Arrow-Root Starch.—This starch, so named from its virtue, as formerly supposed, of curing wounds from poisoned arrows, is extracted from the roots of plants of the *Marantaceæ* of Lindley, more especially from those of the *Maranta arundinacea* and *M. Indica*, natives both of the East and West Indies. There are also other plants which afford a starch, designated by the same title and the name of the locality of its production. Such is the Portland arrow-root, extracted from the *Arum maculatum* of the order *Aroideæ;* the Brazilian arrow-root, from the *Jatropha manihot* of the order *Euphorbiaceæ;* East Indian arrow-root, from tubers of the *Curcuma augustifolia* of the order *Zingiberaceæ;* and Tahiti arrow-root, or tacca starch, from the roots *Tacca oceanica* of the order *Taccaceæ*, with many others. Arrow-root is a snow-white powder, and is very much prized as a dietary article, though its estimation in this respect has now considerably diminished. The starch which is contained in cells in the joints of the rhizome or underground stem, is extracted in Jamaica, as Pereira states, in the following manner:—The tubers, when about ten or twelve months old, are dug up, well washed in water, and then beaten to a pulp in large, deep, wooden mortars; this pulp is thrown into a large tub of clean water, well stirred, the matter strained, the residuary pulp expressed and thrown away. The milky liquid thus obtained is passed through a cloth or hair sieve, allowed to settle, and the clear supernatant liquid drained off. More clean water is poured on the white deposit, the whole stirred; and, after the deposition of the solid matter, it is drawn off as before. Finally, the deposit is drained and dried on sheets in the sun, when it is fit for commerce.

In Bermuda, and in the Island of St. Vincent, the tubers are carefully deprived of their paper-like scale, as this is said to contain a resinous matter which imparts both a color and a disagreeable flavor to the starch; they are then rasped by a machine, or ground by a mill, and the meal being well washed with pure water through various forms of sieves is ultimately dried. To insure greater purity of the product, Ure states that the vessels and cylindrical sieves employed on many of the estates, are constructed of tinned copper; that the scrapers used to remove extraneous matter from the deposit, as well as the shovels with which it is packed in bags, are made of German silver; and that whilst drying, it is protected from dust and insects by a veil of white gauze.

A method similar to that first stated is followed in the East Indies, for extracting the starch from the roots of the same plant, as well as from the *Curcuma augustifolia*, the product of which is distinguished as curcuma starch, or *tikor*, imported from Calcutta. There are two varieties of the latter, the white and the buff-colored tikor, or East India arrow-root, and which can be readily distinguished from the West Indian product, both by its physical properties and by its appearance under the microscope. Pereira states that the white tikor appears to the eye to resemble a finely-powdered salt, such as bicarbonate of soda; that when pinched or pressed by the fingers, it wants the firmness so characteristic of the West Indian arrow-root. The form of the granules under the microscope he states to be different, the curcuma starch being transparent flattened disks of an ovate, or oblong-ovate shape, having a very short neck, or nipple projection, at one extremity where the hilum is situated; and, owing to the flatness of the grains, they have but little lateral shading, except when viewed edgeways, the lines forming only segments of circles. Both these kinds are used for food, like the West Indian product, to which, however, they are deemed much inferior. Portland arrow-root, or Portland sago, so named from being imported from the island of that name, is prepared much in the same way as the foregoing, namely, by scraping the tubers of the *Arum maculatum*, pounding or rasping them in a mortar or machine, washing with water, straining, *et cetera.* It is a white amylaceous powder composed of exceedingly small granules of a circular, muller-shaped, or polyhedral form, having a hilum in a central depression in the grain. This article is likewise used as a dietary.

Cassava Starch.—Known also as tapioca meal and Brazilian arrow-root, is obtained from the roots of the *Jatropha manihot*, a native of Brazil. The roots contain a powerful acrid poison which is readily extracted by water and destroyed by heat, so that, in the course of the preparation of the starch—a process similar to those already described—the poison is entirely separated. It is imported into England from Rio Janeiro, and appears as a white pulverulent substance resembling the genuine arrow-root. Under the microscope the difference is seen at once, this starch being somewhat similar to the Portland arrow-root in the shape of the granules, though much smaller; the hilum circular and surrounded with rings.

Tapioca.—This substance is the meal from the roots of the above-mentioned plant, scraped, washed, and rasped into flour. Whilst still moist it is dried upon hot plates, by which treatment some of the starch grains swell to bursting, and the amylaceous matter thus liberated cements the whole into small irregular masses. Hence tapioca is partially soluble in water. In boiling water it swells up and constitutes a transparent jelly-like mass.

Tahiti or Otaheite arrow-root is obtained from the tubers of the *Tacca oceanica* and *pinnatafida*, a native of Tahiti and other South Sea islands. It is imported into London, and sold under the title of *arrow-root prepared by the native converts at the missionary stations in the South Sea islands.* The tuberous roots, which yield a highly nutritious fecula, are washed and scraped to remove the outer skin, then reduced to a pulp by rubbing on a kind of rasp made by wrapping coarse twine from the cocoa-nut fibre tightly round a board, or, as Ellis states, on a piece of coral; the pulp is then washed with sea-water on a sieve made of the fibrous web that protects the young frond of the cocoa-nut palm. After the deposition of the fecula the liquor is drained off, the sediment made into balls and dried in the sun from twelve to twenty-four hours, then broken up, and the desiccation finished in the sun. This starch has a slight musty odor, though in color it resembles genuine arrow-root. Its particles appear smaller than cassava starch; they are circular, muller-shaped, and polyhedral, having a small circular hilum, and but few and not very distinct rings.

There are a great many other tropical plants from which starch could be extracted, such as the unripe fruit of the plantain and banana, and the tuber of the *dioscorea* or yam, the former of which is stated to afford seventeen per cent. of starch, and the latter nearly twenty-three per cent.

Tous-les-mois.—The starch or fecula bearing this name is allied to the preceding. It is extracted from the tubers of the *Canna edulis*, a native of the West Indies. The seat of its manufacture is principally St. Kitts, whence it was introduced into England in 1836. From the account of Mr. Wordsworth, it appears that the plant grows to the height of four feet or more, and yields a tuber three or four times as large as average-sized potatoes. The fecula is extracted to the amount of twelve and a half per cent. of the tubers by rasping and subsequent washings in the ordinary way. Its granules are much larger than any other kind of starch, not excepting that of the potato; and consequently it may be readily distinguished from the latter by the practised microscopist. In bulk it has a satiny, glistening appearance, somewhat resembling potato starch, but devoid of the dead white of the genuine arrow-root.

Pereira gives the following as the principal distinguishing charactistics of this and potato fecula:—

1. The particles of potato starch are smaller and more irregular in size than those of *tous-les-mois.*

2. The larger particles of potato starch are more irregular in shape than those of *tous-les-mois:* the latter are more constantly rounded-oblong, or ovate-oblong; the former more oval, often approximating to the shape of an oyster or muscle shell, or a triangle with rounded corners, and frequently gibbous or tumid at different parts of their surface.

3. The rings seen on particles of *tous-les-mois* are fine, regular, uniform, concentric, and crowded; those of potato starch are coarser, irregular, often eccentric, irregularly drawn out, distorted, or more and unequally distant from each other. In potato starch a greater number of complete rings are visible, and may be traced round the hilum even in case of many of the larger rings. With *tous-les-mois* only a few of the smaller rings can be thus distinguished.

4. The hilum is situated nearer to the end of the corpuscle in the *tous-les-mois* than that of fecula.

Lastly, When viewed with polarized light the cross is generally less regular in the potato starch grains than in those of the *tous-les-mois.—Pereira.*

Sago.—This is the title of a starch extracted from several varieties of palms very common in Sumatra, Borneo, and other islands of the Indian Archipelago; the word is derived from the Malay name, *sagu*, for the palm and the farina itself. The genuine sago is imported into England from Singapore in large quantities, but a fictitious kind is made at home in many of the starch manufactories from fecula and wheat starch. The real plant which affords the sago is still undefined, for several of the species are known to yield it, those of the *Sagus* and *Sagurus* being the most important. The *Sagus rumphii*, *Sagus inermis*, *Metroxylon sagus*—the *rambija* of the Malays—*Corijota urens*, or sago palm of Assam, *Borassus gomuto*, and a few others are the most resorted to, together with several species of *Zamia*, *Corypha*, and *Mauritia.* In most of these trees the pith is so abundant as to constitute a great part of the bulk of the entire stem, which from its rapid growth often attains to a thickness of a foot or more in diameter in the course of six or seven years. From such a tree it is stated that as much as three hundred-weight of sago can be obtained.

The method adopted for extracting the medullary matter from the tree and separating the starch from it is somewhat different from that followed in preparing arrow-root starch; but the mode of preparing the sago bears so much resemblance to the European system of preparing grain starch, that it will be unnecessary to enlarge upon it in detail. In the Moluccas, the tree when sufficiently matured is cut down near the root, and then divided into portions averaging seven or eight feet in length, which are split open and the pith extracted. By various means—such as pounding in a mortar, *et cetera*—this substance is reduced to a coarse powder, which is agitated with water and submitted to the usual siftings and washings; the farina is then allowed to deposit, and on drawing off the fluid and drying the residue, the *raw sago meal* is obtained. From this the granulated and pearl sago is prepared, after submitting it to a bleaching process preparatory to granulation. To bleach it, the sago meal or flour, mixed with water to the consistence of cream, is exposed in close vessels to the agency of sulphurous acid or chlorine, or to a solution of hypochlorite of lime or soda, and afterwards well washed; a little sulphuric acid being mixed with the washing water when the hypochlorite is used.

In New Guinea the granulation is performed by making a paste of the sago meal with water, and passing this through a sieve into a very shallow iron pot placed over a fire. The particles on being heated assume a globular form. Blume states that the same method is followed in Singapore by the Chinese, only that during the heating the particles are constantly stirred and turned; he adds, that though the material is quite white at the commencement, it gets hard and somewhat pellucid during the process. Pereira says that the tapioca sago of Guibort is submitted to the action of heat, but so well managed is the operation, that none of the substance is in the least charred. He adds that some of the sago of the shops presents no appearance of having been heated, and in this case it is supposed that the granulation is effected by a mill. Two kinds of granulated sago are known in commerce —the common brown or red, and the white or pearl sago. The color is attributed by PLANCHE to the red matter contained in the variety of palms from which the starch is extracted, and by the application of the heat required for granulation altered to a grey, which is the usual color of unrefined sago. Formerly the imported article presented a great inequality of aggregation, varying from very small grains to that of pearl barley or peas, the substance being, however, identical in both, and evidently composed of cemented particles of sago meal. Pearl sago dates from a recent period; CRAUFORD, whose account of it was the first published, states that the method of manufacturing it was discovered by the Chinese of Malacca, a few years previous to 1820, the year in which he wrote. It is met with in pearl-like grains of an irregularly globular form, ranging from the size of a poppy to that of white mustard seed or a little larger. The surface of the larger grains is generally smooth and even, but that of the smaller kinds is uneven and somewhat tuberculated. Under the microscope, the particles of this variety present the same appearance as that of the colored product and sago meal, except that the most of them appear ruptured from the action of the heat. Sago when granulated possesses the property of considerably swelling in hot water or other liquids, without losing its adhesive power; hence the grains appear translucent and gelatinous, but not as slimy globules. The following table by PLANCHE exhibits the quantity of water which the different varieties of sago met with in commerce take up in softening, as also the chief distinctions of the farina itself:—

Source.	Color.	Water absorbed in softening. Per cent.
Maldines,.....	Grains, mostly red, some white,..	150
Sumatra, ...	Grains, white or dirty-white,....	134
New Guinea,	Grains, brick-red or lighter, ...	121
Moluccas,....	Red variety, ...	130
Do., ...	Grey, ...	109
Do., ...	White,...........................	164

Of late years, more especially in Germany and France, considerable quantities of artificial or fictitious sago have been manufactured from inferior starches, such as fecula. The process is simple, consisting merely of submitting the starch after air-drying to a temperature of 212° on iron plates, and thus causing the granules to swell to such a degree that some of them burst, when the gummy matter forms a cement that envelopes other granules. Care must be taken that the heat does not rise so high as to discolor the matter by partial charring, which would be highly detrimental. After the heating the mass is passed through a mill, or sifting and rolling machine, by which it is reduced to the globular form of pearl sago. When dry wheat or potato starches are operated upon, a previous moistening is necessary in order to incorporate as much water as will facilitate the swelling and fracturing of the granules at the comparatively low heat necessary to insure its cementation.

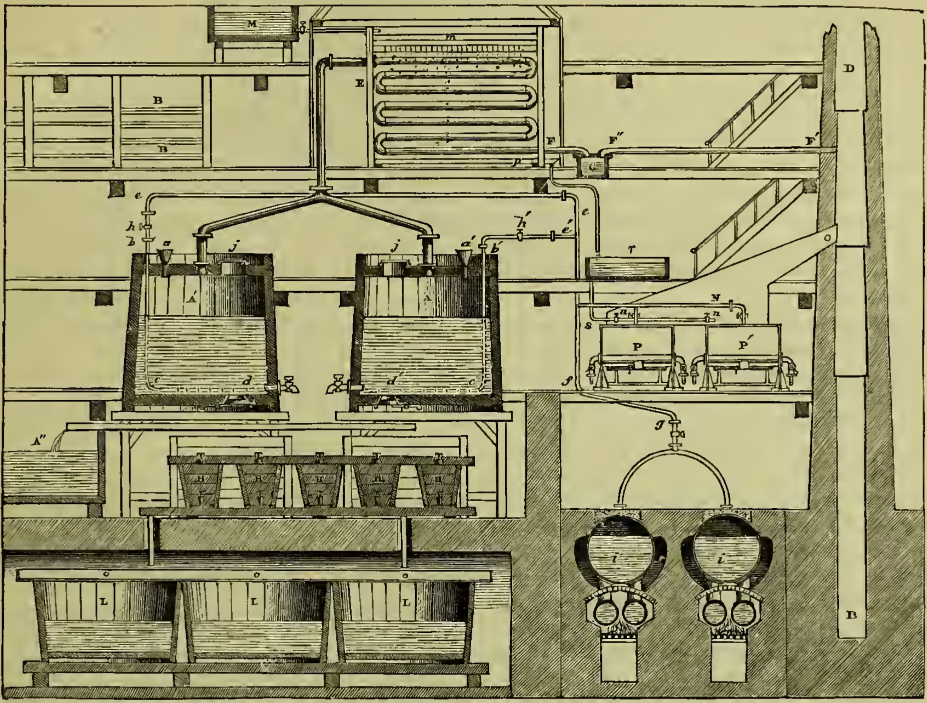
DERIVATIVE PRODUCTS FROM STARCH.—Two products are obtained from starch which are very extensively employed, not only by themselves, but also for the production of other substances of considerable importance. These are *dextrin* and *glucose*, of each of which it will be necessary to give a short account.

Dextrin.—This substance has been briefly described under the term BRITISH GUM in Vol. II., page 313; but its importance deserves that some further details should be given here. It is a substance immediately produced from, and isomeric with starch, and is so called from its property of diverting to the right a ray of polarized light transmitted through its solution. It is soluble in water and in dilute spirit of wine, but insoluble in absolute alcohol. A solution of iodine does not alter its color in solution, except when the transformation of the starch is incomplete, in which case it produces a violet, shading off to a red tint. When the colorless solution of this substance in hot or cold water is evaporated, a viscous mass is obtained, which, on being dried, yields the dextrin in a mass somewhat resembling gum-arabic; it is similar also in its properties, so much so that in many applications it is substituted for gum-arabic at a great saving; and hence the trade that has sprung up of late years in this substance under the title of British gum, *leiocomme*, *et cetera.* It does not, however, like gum-arabic, yield derivatives, such as mucic acid and the like, when treated with nitric acid and other agents, and in this respect a marked chemical distinction is established between the two substances. On the methods resorted to for its preparation, the Editor has nothing to add to the details given at the page above referred to.

Glucose.—In starch factories, especially on the Continent, a considerable quantity of starch or potato fecula is converted into glucose—a species of sugar which is found in many kinds of fruit, especially the grape, and into which all other varieties of sugar, whether it be the product of the cane, maple, or beet, is readily resolved by the action of acids and other chemical agents. The chief use to which glucose is applied on the Continent is for the manufacture of beer, and a coarse kind of alcohol, which is said to be extensively converted into French brandy by the addition of oil of raisins, coloring matter, *et cetera.* There are two methods by which the starch, or rather dextrin, is converted into glucose; the one is well exemplified in all the breweries and distilleries of the kingdom, where thousands of tons are annually formed in the preliminary stages of malting and mashing; the other consists in the use of sulphuric acid, which is a more expeditious method, and gives a purer product than when the conversion is effected by means of diastase. The process is naturally divided into six stages, namely, the conversion of the starch into dextrin, the saccharification of the dextrin, the settling of the liquid, the evaporation, the filtration, and the concentration. PAYEN describes the apparatus and operations connected with it as follows:—

The saccharification of the starch is effected in large tubs or vats, A A′—Fig. 553—constructed of stout wood, to contain two thousand eight hundred gallons. In one of these, A′, a lead pipe, *b c d*, coiled at the bottom, is placed, the circular portion being cut or perforated for the introduction of steam to heat the acidulous water with which it is two-thirds filled; the steam from the generator, *i*, is admitted to it at pleasure by means of the pipe, *b f e g*, and stopcock, *h*. During the operation the vat is covered, and the disengaged vapor conducted to the chimney, B D; but before escaping it may be utilized in evaporating the sirup by conveying it through serpentine pipes, E, F. By such arrangements the disagreeable odors resulting from the evaporation of the oil of the starch are considerably abated, being partly condensed in the serpentine pipe, so as to flow off with the water produced from the steam into a vessel interposed between the pipes, F, G, and partly carried away by the pipe, F′, F″; or the uncondensed vapors may be conducted into the fire where any remaining traces of essential oil are consumed, and thereby the nuisance is almost entirely prevented.

Fig. 553.



When it is proposed to convert two tons of fecula in such an apparatus, the substance is suspended in portions of two hundredweight in a trough or tub, with twenty-two gallons of water, and when thoroughly steeped, it is introduced by a funnel, *a*, in quantities of four to five gallons at a time, into the large tub or vat, which should be previously charged with about thirty-two barrels of water, and three quarters of a hundred of sulphuric acid agitated with it, the whole being raised to 212° by forcing steam into it. This temperature is maintained till all the fecula is introduced, and it is found that the transformation is accomplished in thirty or forty minutes after the last portion of the starch has been added. The point at which the change is completed is easily ascertained by simply testing a few drops of the clear liquid with a drop of a solution of iodine, when, if the saccharification be effected, no coloration takes place; in the contrary case the characteristic violet of iodide of starch manifests itself. After the conversion into glucose, the introduction of the steam is suspended, and the next operation is the saturation of the free acid by means of carbonate of lime, and the consequent precipitation of sulphate of lime. The latter being but sparingly soluble, most of it falls to the bottom. It requires from ninety to a hundred pounds of chalk to saturate the whole of the free acid; and this must be introduced gradually to guard against the evolution of too much carbonic acid at once. If an excess of lime be used, it prevents the solution from clarifying so readily as when the sulphuric acid is barely taken up; this is shown by the cessation of effervescence, and the inability of the liquid to change the blue color of litmus to more than a feeble purple tint. When the saturation is completed, the mixture is either permitted to repose in the same vessel, or if it be required to operate upon another batch at once, it is drawn off into the lower vat A″, where it is left at rest during twelve hours; the clear liquid is then racked through coarse bone black in the filters, H, H, the deposit of sulphate of lime being also thrown upon cloth filters, where it is drained and washed. The sirup as it flows off from the filter, having a density of 1·11 to 1·122, is retained in the reservoirs, L, L, L, from which it is raised by a pump or a chain of buckets to the reservoir M; from this it is distributed in a horizontal channel, *m*, by numerous lateral apertures upon the serpentine evaporator, E F, and then flows by a channel, *p*, and tube, *q*, into a receiver, *r*, whence it can be drawn at will by the tube, *s*, and stopcocks, *n*, *n*, into the boilers, P, P′, which are heated by steam, and in which the liquid is concentrated to 1·26 specific gravity. The sirup thus obtained, after reposing a sufficient time to allow the sulphate of lime precipitated by the evaporation to subside, is fit for the brewer or distiller; but if intended for the confectioner or liqueur-maker it should be allowed to rest for twenty-four hours, filtered when cold through coarse bone black, and casked immediately. When it is desired to obtain the glucose in a solid state, the evaporation is carried so far as to concentrate the sirup to 1·38 or 1·39 specific gravity—73° to 74° Twaddell; it is then poured into the cooler, where it is left till the crystallization commences, and thence transferred to the tuns in which the solidification is effected.

Of late years, instead of preparing the sugar in an amorphous solid mass, as by the preceding method, it is obtained in grains or regular crystals. The process for converting the starch into sugar is the same as that already described; but care is taken to do it more thoroughly, since any excess of dextrin in the sirup is found to prevent crystallization. After the acid has been neutralized, and the lime salt removed by deposition, *et cetera*, the saccharine liquid is decolorized, and concentrated to 1·300, or 60° Twaddell, in summer; and 1·262 or 53·5° Twaddell, in winter. At these stages it is racked off into large reservoirs where the lime salts settle down; and during this period it is necessary, in order to prevent any fermentation, that the liquid be cooled either by circulation of air or of cold water in a coil placed in the vessel. After thirty-six to forty hours, the sirup, being clarified and cooled to about 65°, is put to crystallize in ordinary tuns furnished with a false bottom placed over the lower one, which is pierced with a number of holes that are stopped with wooden pegs. These tuns are placed on stages along the walls of the room, twelve to fifteen inches above the floor. A sheet of lead, or large canal or sluice, reaches along each range of crystallizing tuns. To avoid the fermentation of the sirup, which in summer often prevents the crystallization, six or seven ounces of sulphurous acid solution are added to the content of each tun. At the end of eight or ten days the crystallization commences and goes on, the crystals depositing in succession. When the bulk of two-thirds of the liquid becomes a mass of crystals, the pegs in the lower bottom are withdrawn, and the still fluid portion is permitted to drain off, the operation being quickened towards the end by tilting two adjoining tuns against one another. The drainings are conducted to the converting tun, where any dextrin the liquor may still contain is saccharified.

The desiccation of the drained sugar was long a work of difficulty, the moisture of the air being sometimes sufficient to convert it again to sirup, which, with the heat of the factory, melted and agglomerated the remaining portion. M. FOUSCHARD has obviated these inconveniences by furnishing the tuns or tubs, R R, with tables of plaster of Paris, which absorb the portion of the interposed sirup. This very much quickens the desiccation of the crystals, especially in a current of air heated to 77°, taking care that the granules are not thereby soldered together. There is, however, a certain amount of the crystallized mass which has to be submitted to a second solution, namely, that which is agglomerated on the end of the loaf resting on the plaster; this must be separated, and the sugar extracted from the sulphate of lime, by grinding them between cast-iron cylinders, and dissolving in the ordinary way.—*Payen.*

Glucose crystallizes in grains formed of a number of lamellar plates radiating from a common centre, and thus forming a kind of bristling spheroid of lamellar points. It has only one-third the sweetening power of cane sugar, whilst it is once and a half less soluble; at 212° it melts in its water of crystallization, which characteristic allows of its recognition when in certain proportions in cane sugar, It may also be detected by the property which glucose possesses of forming definite compounds with alkaline and earthy bases, which compounds suffer decomposition, and become strongly colored brownish, at a temperature between 160° and 212°, which is not the case with cane sugar under like circumstances.

Glucose is composed of $C_{12} H_{12} O_{12}$, 2HO, differing from starch, $C_{12} H_{10} O_{10}$, only by an addition of two equivalents of the elements of water, and two equivalents of the water of crystallization, with which, however, it parts when carefully exsiccated, leaving the compound of the composition $C_{12} H_{12} O_{12}$.

STRONTIUM.—Although less abundantly diffused, it resembles barium both in its chemical and geological relations. Like it strontium is never found native, but only as *carbonate* and *sulphate*. It was first recognized by HOPE in 1792, in the mineral *strontianite*, so called from Strontian in Scotland.

Pure strontium was first made by BUNSEN and MATTHIESSEN in 1855; impure by DAVY in 1807. It is prepared by electrolysis from chloride of strontium. It is a golden-yellow metal, of considerable metallic lustre, harder than lead, and ductile. It melts at a red heat. Heated in air, it inflames and burns with a bright lustre in oxide. In dry air it remains untarnished; but it decomposes water, even at ordinary temperatures, with singular vehemence. Fuming nitric acid does not attack it; but dilute acids oxidize it readily. It burns in chlorine, iodine, bromine, and sulphur atmospheres, producing the corresponding compounds. Strontium has a specific gravity of 2·542, and an equivalent weight of 44. It is only in a strictly scientific light that this metal and its compounds are of any importance, excepting the chloride and nitrate, which are much used by pyrotechnists. The chemical symbol of the metal is Sr.

A few of its principal compounds are briefly described in the following:—

OXIDE OF STRONTIUM—*Strontia.*—This base is most easily obtained by igniting the nitrate. It is greyish-white, and of specific gravity 3·932. It is neither fusible nor volatile. For water it shows powerful affinity, and forms a *hydrate.* This is soluble in fifty times its weight of cold, and 2·4 parts of boiling water. From the latter it separates in crystals belonging to the square prismatic system. Nine equivalents of water are easily expelled by heat; but it requires a temperature approaching white heat again to render the hydrate anhydrous. Both strontia and its hydrate readily absorb carbonic acid. The symbol of strontia is SrO, and the equivalent 52; the symbol of the hydrate is $SrO\ 9\ HO$.

Carbonate of Strontia is found native as strontianite, both massive, and in forms belonging to the square prismatic system. It is most readily prepared pure by precipitating the nitrate or chloride with carbonate of ammonia. The artificial carbonate is beautifully white and soluble in one thousand five hundred and thirty-six parts of boiling water. It is more soluble in aqueous solution of carbonic acid, and separates in needles when evaporated. Heated to bright redness in a stream of watery vapor it loses its carbonic acid, and becomes changed into strontia. The symbol is SrO, CO_2; Eq. 74·00; specific gravity, 3·605.

Sulphate of Strontia is the *celestine* of mineralogists. Sometimes massive, it is often found beautifully crystallized in prisms isomorphous with sulphate of baryta. Artificially it may be prepared by precipitation from any of its soluble salts, either by sulphuric acid or a soluble sulphate. It has the form of a white tasteless powder, soluble in fifteen thousand parts of cold, and three thousand eight hundred and forty parts of boiling water. In solutions of common salt it is slowly but completely soluble. A solution of sulphate of strontia precipitates salts of baryta. The symbol is SrO, SO_3; Eq. 92·00; specific gravity, 3·95.

Nitrate of Strontia separates from concentrated solutions in transparent colorless octohedra, soluble in five parts of cold, and half their weight of boiling water; insoluble in alcohol. It has a sharp, cooling taste, and decrepitates in the fire, leaving strontia. At low temperatures it crystallizes out from more dilute solutions with five equivalents of water. Nitrate of strontia is much used by pyrotechnists to produce a splendid crimson flame. A mixture of forty parts of the nitrate, five of chlorate of potassa, thirteen of sulphur, and four of the sesquisulphide of antimony, is found a good one in practice, but *great care* is necessary in the admixture. The symbol is SrO, NO_5; Eq. 106·00; specific gravity, 2·704.

On the large scale the nitrate is prepared by heating pounded celestine with one-third of its weight of bituminous coal, dissolving the resulting sulphide in water, and decomposing with dilute nitric acid.

Chloride of Strontium is in long, six-sided needles, deliquescent in moist air, and soluble in three-quarter parts of cold water. It imparts an intense crimson color to flame. In alcohol it is also soluble. When heated, the chloride melts and becomes speedily anhydrous. Ignited in air, it loses chlorine and absorbs oxygen. The chloride of strontium is most easily prepared by dissolving the sulphide in water, and decomposing with hydrochloric acid. The symbol for the salt is $SrCl, 6\ HO$.

General Character of the Salts of Strontia.—They are colorless; not poisonous, like most of those of barium. Before the blowpipe they communicate a crimson color to flame. Neither hydrofluosilicic acid nor hyposulphite of soda precipitates them. The chromate of strontia is sufficiently soluble to be employed as a test for baryta; but oxalic acid produces immediate turbidity in them. On addition of sulphate of lime to a solution of a salt of strontia, there arises gradually a white precipitate of sulphate of strontia; immediately when heated.

Strontia is always determined in analysis as sulphate or carbonate; one hundred parts of the former contain 56·52 of strontia, and of the latter 70·27 parts of this base.

SUGAR.—*Sucre*, French; *Zucker*, German; *Saccharum*, Latin.—Sugar seems to come more directly from the Persian *Shukkur*, which is nearly the same as the English pronunciation. The Arabic name is similar, and the probable origin of both is said to be the Sanscrit *Sarkara.* In the old Assyrian and Phœnician languages there was no letter *k*, but both nations called the substance *suicar* or *suicra.* It is said by Humboldt to have been known in very early times in China. It is probable that in early historic times it was brought as a luxury and a curiosity into Western Asia and Europe. The Hebrew word for being intoxicated is *Shacar*, and strong drink *Shecar.* These words were believed to have an intimate connection with sugar; but this could only occur in a country where sugar was so well known that its ready passage into alcohol was familiar. Such was not the case in Western Asia or Syria and the surrounding countries in known times, although it may have been so at an earlier period. In the Bible is mentioned *sweet calamus* two hundred and fifty shekels; and *calamus* and *cinnamon* in Solomon's Song; *sweet cane* in Isaiah, and in Jeremiah and Ezekiel. There is little difficulty in believing the scriptural writers to be the earliest who allude to sugar. Persons in frequent communication with the East were sure to obtain its products before the Greeks. Herodotus speaks of manufactured honey, supposed to mean sugar; and Strabo mentions that Nearchus, one of Alexander's admirals, speaks of a reed which yields honey without bees in India. Theophrastus mentions it as a honey obtained from a reed which grew in moist places in Egypt, and had a sweet root. This sweet root has been used as a proof that he did not allude to the cane. The mention of moist places also is an objection; but so many canes do grow in moist places that one readily forgives this error and others, seeing that the fact of sweet matter from a cane is so distinctly spoken of. Theophrastus speaks of honey from reeds, evidently cane sugar. Eratosthenes alludes to roots in India sweet to the taste even when boiled, as if it were the custom to boil them to remove the sugar. Varro speaks of the juice of an Indian root so sweet that, when pressed out, no honey can contend with it. Dioscorides says that there is a kind of honey called *saccharus* which is found in reeds in India and Arabia Felix, having the appearance of salt; but it was only used in medicine. If found in Arabia it might well have been known early in Syria. Pliny says that there is a kind of honey which collects in reeds, white like gum, and brittle to the teeth; the larger pieces about the size of a filbert, and only used in medicine. Statius speaks of boiling canes in Ebosita; but that place is not known. Arrian mentions it as an article of Indian commerce; and Ælian speaks of it as pressed from reeds on the Ganges. It is well to add that Dr. Adam, the learned editor of Paulus Egineta, says that the saccharum of Theophrastus, Dioscorides, Galen, Strabo, and Pliny was a concretion formed on various reeds, but especially on the bamboo cane; also, that Moses Chorenensis, fifth century, first mentions the boiling of canes. This may account for the bitterness and medicinal qualities mentioned by Dioscorides and others. Albertus Agnensis relates that the crusaders found sweet honeyed canes in great quantity in the meadows near Tripoli in Syria, which reeds were called Zucra. These the crusaders sucked, and were much pleased with the sweet taste of them, with which they could scarcely be satisfied. This plant is cultivated, the author states, with great labor of the husbandmen every year. At the time of harvest they bruise it when ripe in mortars, and set by the strained juice in vessels, till it is concreted in the form of snow or of white salt. This, when scraped, they mix with bread, or rub it in water, and take it as pottage; and it is to them more wholesome and pleasing than the honey of bees. The people who were engaged in the sieges of Albaria Marra and Archas, and suffered dreadful hunger, were much refreshed thereby. Again, Jacobus de Vitriaco mentions reeds full of honey in Syria, pressed out by a screw and concreted by fire. Willermus Tyrensis speaks of it as being an article of export from Tyre; it seems to have at that time spread over all the Levant, and in the time of the Emperor Barbarossa it was made in Sicily, and used both solid and as a sirup. Sugar is said to have been imported into Venice as early as 991. It was brought from Sicily and Egypt—cheaper from Sicily—in the twelfth century. In 1166 William II. gave a mill for grinding sugar canes to the monastery of St. Bennet. It travelled into Valencia, thence to Granada and Murcia. About 1420 the Portuguese took it to Madeira and Spain, and to the Canaries. Thence, says Dr. Moseley, the cultivation of the sugar cane and the art of making sugar were extended by different nations of Europe to the West Indian islands and the Brazils.

In 1518 there were twenty-eight sugar works established by the Spaniards in Saint Domingo; and Hawkins brought some of the sugar to England in 1563. Antwerp had exported it about the same time —1560. The English planters were realizing great wealth in Barbadoes in 1650, although the Portuguese supplied the most of Europe then with Brazil sugars.

The name sugar is used in the arts to denote certain substances in the vegetal and animal kingdoms, whose chief characteristics are a sweet taste and the power of undergoing, either directly or indirectly, vinous fermentation, that is, of splitting up under the influence of yeast almost wholly into carbonic acid and alcohol. Four principal kinds of sugar are known, namely, *cane*-sugar, so called from the fact that its chief source is the sugar cane, though it is found in large quantities in other plants, such as the stalks of maize or indian corn, the maple, birch, palm, the beet-root, carrot, turnip, and in a large number of tropical fruits; *fruit* sugar is that to which acidulous fruits owe their sweetness, and hence its designation; it does not crystallize, and exists in large quantities in treacle. The third variety is called *grape* or *starch* sugar, owing to its being found in ripe fruit, such as dried raisins, figs, and the like, or from the fact that it may be produced in quantities from starch; and the fourth kind, called *milk* sugar, is exclusively found in the lacteal fluid of animals.

A remarkable feature in all these varieties of sugar is, that two of the three elements of which they are composed, namely, hydrogen and oxygen, are so proportioned as to constitute water, or, in other words, that they contain the same number of equivalents of these elements. This fact has led to sugars being designated *hydrates of carbon;* but from such terms it is not to be understood that the hydrogen and oxygen really exist as water, but rather that their combination, in the proportion in which they are found in the sugar admits of the expression. The composition of the different kinds of sugar varies only in the elements of one or more equivalents of water; to which fact may be attributed the readiness with which one species is changed into another, merely by the assimilation of that liquid. This feature in the composition of sugars extends to other substances not possessing the same properties, but readily convertible into particular kinds by certain chemical operations, such as the several starches, dextrin, inulin, gum, and several others. The following tabular view of the chemical composition of the sugars and a few of the above mentioned substances will at once exhibit the great analogy in composition between the two classes of bodies:—

Name.	Composition.	
Cane sugar, or sucrose, ...	$C_{24} H_{22} O_{22}$	$= C_{12} H_{11} O_{11}$
Fruit sugar, or fructose,....	$C_{12} H_{12} O_{12}$	$= C_{12} H_{12} O_{12}$
Starch sugar, or glucose, ...	$C_{12} H_{12} O_{12}$, 2 HO	$= C_{12} H_{14} O_{14}$
Milk sugar, or lactose, ...	$C_{24} H_{19} O_{19}$, 5 HO	$= C_{12} H_{12} O_{12} \times 2$
Manna sugar, or mellitose,...	$C_{24} H_{24} O_{24}$, 4 HO	$= C_{12} H_{14} O_{14} \times 2$
	Starch and gum group.	
Starch,........	$C_{12} H_{10} O_{10}$	$= C_{12} H_{10} O_{10}$
Dextrin, ...	$C_{12} H_{10} O_{10}$	$= C_{12} H_{10} O_{10}$
Inulin, ...	$C_{24} H_{21} O_{21}$	$= C_{12} H_{10} O_{10} \times 2 + HO.$
Gum, ...	$C_{12} H_{11} O_{11}$	$= C_{12} H_{11} O_{11}$
Cellulose,.....	$C_{12} H_{10} O_{10}$	

From a comparison of the formulas in the foregoing table, it will be observed that the amount of carbon in the several varieties remains the same, but that the elements of water present slightly vary, and to these their distinct and diverse properties is to be attributed.

Cane-sugar. — *Common sugar* is manufactured chiefly from the sugar cane, but large quantities are prepared also from the sap of the maple tree and from beet-root.

Preparation.—To make pure cane-sugar the same course of operations should be followed as will be described in preparing and refining sugar, each being executed with greater care and attention; hence it will be needless to detail the process here.

Properties.—Cane-sugar when pure, as in the finest lump, has a glistening white appearance, resulting from the multifarious reflections and refractions of light from the numerous congeries of small crystals composing it. When a very concentrated solution of this substance is left to crystallize spontaneously, it forms rhomboidal prisms with dihedral summits of considerable dimensions, especially if the nuclei be transferred repeatedly to concentrated menstrua. Thus crystallized it forms the sugar candy of the shops, and appears transparent. According to PLAYFAIR and JOULE its specific gravity is 1·594. It is soluble in about one-third of its weight of cold, and in all proportions in boiling water, forming in either case transparent colorless sirups. A solution saturated with sugar at 212° deposits a part in crystals—the candy already mentioned—on cooling. If the temperature at which the saturation is effected be raised to 230°, the whole forms a concrete granular mass when allowed to cool. This is not the case when the sirup is rapidly boiled down to the same density; for then it congeals on a cold surface in a transparent amorphous mass, which on exposure becomes opaque, owing to a fibrous crystallization radiating from the surface inwardly. In this state it is ordinarily called *barley sugar*, the change from the crystalline state being due to a dimorphism caused by the heat, analogous to that which sulphur exhibits under almost similar circumstances. Continuous boiling of a weaker sirup has a like effect. The same change, from the crystallizable to the noncrystallizable modification is effected in the cold by the prolonged contact of dilute mineral acids. Noncrystallizable cane-sugar has the composition $C_{12} H_{11} O_{11}$, HO. It is gradually converted by long-continued contact with water, especially in the presence of acids, without undergoing any chemical change, into glucose or grape-sugar—$C_{12} H_{12} O_{12}$, 2 HO—a substance which crystallizes in acicular tufts. Dilute alcohol of specific gravity 0·830 takes up about a quarter of its weight of sugar. Absolute alcohol dissolves a small quantity of it at the boiling point, but deposits it again on cooling. When the crystals of candied sugar are broken, a slight phosphorescence is discernible, and a similar phenomenon is produced on rubbing two pieces of lump sugar together. Heated to 212°, no further effect is produced on crystallized cane-sugar than the expulsion of the mechanical moisture contained in its interstices. At 320° it melts; and though not decomposed, still, as PROUT remarks, several of its characteristics are destroyed. Between 320° and 350° the liquid mass becomes transparent on cooling, though, from circumstances such as those mentioned in reference to barley sugar, the transparency is destroyed after some time. At 410° it changes to an orange-yellow, afterwards to a reddish-brown hue; and if this heat be maintained, it is converted into a new acid compound of a brownish color very soluble in water—*caramel*—with the loss of three equivalents of water. If the heat be further increased, complete decomposition takes place, with evolution of inflammable gases mixed with carbonic acid, pyrogeneous oils, and acetic acid; and a carbonaceous residue, forming about a quarter of the weight of the original substance, remains.

Cane-sugar combines directly with the oxides of the alkalies and of the alkaline earths, forming with them sugarates—improperly called sometimes saccharates; and also with certain salts, particularly with chloride of sodium. The potassa and soda compounds, which are both unstable and indefinite, are obtained as sirupy liquids on adding a strong aqueous solution of the alkali to a solution of sugar in alcohol. Their compositions are—

$$NaO,\ C_{12} H_{11} O_{11},$$
$$K\ O,\ C_{12} H_{11} O_{11}.$$

Sugarate of baryta is formed by dissolving one part of caustic baryta in three parts of hot water, and adding the solution to a sirup containing two parts of sugar and four parts of water. A mass of crystals is thus obtained resembling boracic acid, and having the composition—

$$BaO,\ C_{12} H_{11} O_{11}.$$

Sugarate of baryta is difficultly soluble in water, and is decomposed by almost all acids into the corresponding baryta, salt and sugar. Even the carbonic acid of the air effects this change.

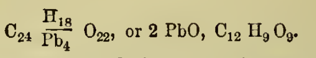
There appear to be three sugarates of lime, of which however the most definite and important has the composition—

$$CaO,\ C_{12} H_{11} O_{11}.$$

This is formed on adding milk of lime to sirup, in the proportion of two parts by weight of lime to thirteen of sugar. After filtration the sugarate of lime is precipitated by alcohol. On drying, this body appears frangible and resinous, and is very soluble in water. This compound has the rare property of being precipitated from its aqueous solution by heat, and of redissolving as it cools. The amount of lime which a sirup takes up is less according as the density of the sirup is greater. The following table constructed by PELIGOT shows this relation—

Quantity of sugar dissolved in 100 parts of water.	Density of sirup.	Density of sirup when saturated with lime.	100 parts of residue dried at 120° contain	
			Lime.	Sugar.
40·0	1·122	1·179	21·0	79·0
37·5	1·116	1·175	20·8	79·2
35·0	1·110	1·166	20·5	79·5
32·5	1·103	1·159	20·3	79·7
30·0	1·096	1·148	20·1	79·9
27·5	1·089	1·139	19·9	80·1
25·0	1·082	1·128	19·8	80·2
22·5	1·075	1·116	19·3	80·7
20·0	1·068	1·104	18·8	81·2
17·5	1·060	1·092	18·7	81·3
15·0	1·052	1·080	18·5	81·5
12·5	1·044	1·067	18·3	81·7
10·0	1·036	1·053	18·1	81·9
7·5	1·027	1·040	16·9	83·1
5·0	1·018	1·026	15·3	84·7
2·5	1·009	1·014	13·8	86·2

The hydrated oxide of copper is dissolved by a mixture of sugar and sugarate of lime, an amorphous double sugarate of lime and copper being formed. The sugarate of lead is not strictly an analogue of the previously described metallic compounds of sugar, which are formed by the direct union of the sugar with the metallic oxide. Sugarate of lead is sugar in which four atoms of hydrogen are replaced by four atoms of lead—



$$C_{24}\,\frac{H_{18}}{Pb_4}\,O_{22},\ \text{or}\ 2\,PbO,\ C_{12}\,H_9\,O_9.$$

It is produed as a gelatinous precipitate on mixing an ammoniacal solution of acetate of lead with a solution of sugar. After washing with cold it is dissolved in hot water, and allowed to stand closed from the air. The compound gradually separates out as white crystals. Massicot also gradually combines with sugar, forming the same compound, water being liberated at the same time.

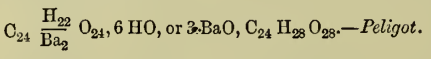
The chloride of sodium likewise combines directly with cane-sugar. If four parts by weight of sugar and one part of chloride of sodium be dissolved together in water, and allowed to evaporate spontaneously, the excess of sugar first crystallizes out; the mother-liquor, on further evaporation, deposits crystals which deliquesce in moist air, of the composition, according to GERHARDT, of—

$$NaCl,\ C_{24}\,H_{22}\,O_{22}.$$

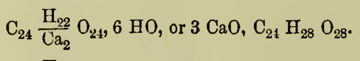
GLUCOSE, or grape-sugar, occurs in raisins, currants, and other dried ripe fruits, and in flowers. It occurs also in honey and in the urine of patients affected with diabetes, accompanying in all the above cases noncrystallizable cane-sugar. It is found also in the blood, the bile, and in eggs. Both starch and cellulose are converted into glucose by digestion with dilute sulphuric acid. The substance which appears near the germinating point at the time of germination of the cereals, called diastase, or in its crude and impure form, yeast or barm, has also the power of transforming starch into grape-sugar, for there is no evidence to show that the substance which changes starch to glucose, is other than that which changes glucose into alcohol and carbonic acid.

Aqueous alcohol dissolves all these kinds of sugar, cane-sugar, grape-sugar, and noncrystallizable sugar, in proportions greater according to the degree of dilution of the alcohol. Absolute alcohol dissolves the noncrystallizable sugar alone. This behavior is made the basis of a method of assaying sugars, as will be shown further on.

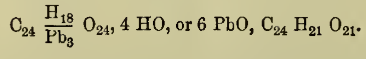
For further particulars concerning the properties and composition of this substance, see article STARCH—subheading *Glucose*—page 962. Glucose, like *sucrose* or cane sugar, combines with the metallic oxides to form the following glucosates—



$$C_{24}\,\frac{H_{22}}{Ba_2}\,O_{24},\ 6\,HO,\ \text{or}\ 3\,BaO,\ C_{24}\,H_{28}\,O_{28}.\text{—}\textit{Peligot.}$$



$$C_{24}\,\frac{H_{22}}{Ca_2}\,O_{24},\ 6\,HO,\ \text{or}\ 3\,CaO,\ C_{24}\,H_{28}\,O_{28}.$$



$$C_{24}\,\frac{H_{18}}{Pb_3}\,O_{24},\ 4\,HO,\ \text{or}\ 6\,PbO,\ C_{24}\,H_{21}\,O_{21}.$$

It also combines with chloride of sodium forming—

$$C_{24}\,H_{24}\,O_{24}\ Na\ Cl,\ 2\,HO.$$

Glucose forms with sulphuric acid a copulated acid whose salts are both unstable and incompletely examined With nitric acid a detonating compound is produced. Mannite forms with nitric acid a similar detonating body.

MANNITE—$C_{12}\ H_{14}\ O_{12}$—called also the sugar of mushrooms, is chiefly extracted from manna, an exudation from the *Fraxinus rotundifolia;* it is also found in celery, dog's tooth, fennel, *et cetera*, and in algæ. Mannite is one of the products of the fermentation of starch and glucose; it is produced in the transformation of starch into glucose by dilute sulphuric acid. It is readily obtained from manna by boiling it with strong alcohol; on filtering and allowing the filtrate to cool, it crystallizes out, and is purified by recrystallization from alcohol. Mannite does not readily ferment. Owing to this, it may be freed from the other sugars by submitting the liquid which contains them all to fermentation, and extracting the mannite from the unfermented residue. It is supposed that the gradual loss of sweetness effected by time on wine is chiefly due to the slow transformation which the mannite they retained after the first fermentation undergoes. Direct experiments have shown that mannite does suffer such a fermentation.

Sugar of Milk—$C_{24}\ H_{20}\ O_{20}$, 2 HO—otherwise called lactine or lactose, occurs in the milk of the mammiferæ, from which it is extracted by precipitating the caseum by a dilute acid, filtering, and evaporating to dryness.

Sorbine—$C_{24}\ H_{24}\ O_{24}$—is found in a few plants.

Mosite—$C_{24}\ H_{24}\ O_{24}$, 4 HO—occurs in the juice of flesh, it is very soluble in water; insoluble in alcohol and ether; at 212° it loses four atoms of water.

Cane-sugar, both crystallizable and noncrystallizable, and glucose, are all capable of alcoholic fermentation. But the action of the ferment is, in the first place, to transform both the former kinds of sugar into glucose or grape-sugar.—See ALCOHOL.

Testing or Estimation of Sugar.—If a watery solution contains only one of the three kinds of sugar —namely, cane-sugar, crystallizable; cane-sugar, noncrystallizable; or grape sugar, glucose; the amount of sugar may be determined from the specific gravity of the sirup. In all cases the density of the sirup is increased by an increased quantity of saccharine matter.

The following table from Dr. URE's Dictionary shows the specific gravity at 60° of solutions of crystallizable cane-sugar containing various amounts of sugar in one hundred parts by weight of the sirup :—

Sugar in one hundred parts by weight.	Specific gravity at 60°
66·666	1·3260
50·000	1·2310
40·000	1·1777
33·333	1·4400
31·250	1·1340
29·412	1·1250
26·316	1·1110
25·000	1·1045
21·740	1·0905
20·000	1·0820
16·666	1·0685
12·500	1·0500
10·000	1·0395

The subjoined more extended table has been constructed by PAYEN for a similar purpose. It shows the density at 59° of sirups formed by dissolving one hundred parts by weight of sugar in different quantities of water. The values differ somewhat widely from those given by Dr. URE :—

Parts of sugar.		Parts of water.		Specific gravity.
100	dissolved in	50	give a sirup of	1·345
100	"	60	"	1·322
100	"	70	"	1·297
100	"	80	"	1·281
100	"	90	"	1·266
100	"	100	"	1·257
100	"	120	"	1·222
100	"	140	"	1·200
100	"	160	"	1·187
100	"	180	"	1·176
100	"	200	"	1·170
100	"	250	"	1·147
100	"	350	"	1·111
100	"	450	"	1·089
100	"	550	"	1·074
100	"	650	"	1·063
100	"	750	"	1·055
100	"	945	"	1·045
100	"	1145	"	1·030
100	"	1945	"	1·022
100	"	2445	"	1·018
100	"	2945	"	1·015

The annexed table, constructed by Neimann at the normal temperature of 63°, with the same object, is also submitted :—

Sugar.	Water.	Specific gravity	Sugar.	Water.	Specific gravity.
0	100	10·000	36	64	1·1582
1	99	1·0035	37	63	1·1631
2	98	1·0070	38	62	1·1681
3	97	1·0106	39	61	1·1731
4	96	1·0143	40	60	1·1781
5	95	1·0179	41	59	1·1832
6	94	1·0215	42	58	1·1883
7	93	1·0254	43	57	1·1935
8	92	1·0291	44	56	1·1989
9	91	1·0328	45	55	1·2043
10	90	1·0367	46	54	1·2098
11	89	1·0410	47	53	1·2153
12	88	1·0456	48	52	1·2209
13	87	1·0504	49	51	1·2265
14	86	1·0552	50	50	1·2322
15	85	1·0600	51	49	1·2378
16	84	1·0647	52	48	1·2434
17	83	1·0698	53	47	1·2490
18	82	1·0734	54	46	1·2546
19	81	1·0784	55	45	1·2602
20	80	1·0830	56	44	1·2658
21	79	1·0875	57	43	1·2714
22	78	1·0920	58	42	1·2770
23	77	1·0965	59	41	1·2826
24	76	1·1010	60	40	1·2882
25	75	1·1056	61	39	1·2933
26	74	1·1103	62	38	1·2994
27	73	1·1150	63	37	1·3050
28	72	1·1197	64	36	1·3105
29	71	1·1245	65	35	1·3160
30	70	1·1293	66	34	1·3215
31	69	1·1340	67	33	1·3270
32	68	1·1388	68	32	1·3324
33	67	1·1436	69	31	1·3377
34	66	1·1484	70	30	1·3430
35	65	1·1538			

The following is most used :—

TABLE OF THE DENSITY OF SOLUTIONS OF SUGAR, ACCORDING TO BEAUMÉ.

Degrees.	Sugar per cent.	Degrees.	Sugar per cent.	Degrees.	Sugar per cent.
1	1·8	13	23·7	25	46·2
2	3·5	14	25·6	26	48·1
3	5·2	15	27·6	27	50·0
4	7·0	16	29·4	28	52·1
5	8·7	17	31·5	29	54·1
6	10·4	18	33·4	30	56·0
7	12·4	19	35·2	31	58·0
8	14·4	20	37·0	32	60·1
9	16·3	21	38·8	33	62·2
10	18·2	22	40·6	34	64·4
11	20·0	23	42·4	35	66·6
12	21·8	24	44·3		

Payen gives the subjoined empirical formula for the estimation of the amount of sugar in a sirup from the indications of its gravity with Beaumé's areometer, namely—multiply the indicated density by two and deduct a tenth of the product, the remainder will represent the per centage of sugar in the liquor. Thus, if the indication observed be 20, the result will be—

$$20 \times 2 \textit{ minus } \frac{20 \times 2}{10} = 36{\cdot}0 \text{ per cent.}$$

If the sirup be of pure crystallized sugar the product of the density multiplied by two is reduced by one-twelfth ; thus—

$$20 \times 2 \textit{ minus } \frac{20 \times 2}{12} = 36{\cdot}67 \text{ per cent.}$$

If, however, a sirup contains other solid bodies besides sugar, it is clear that the specific gravity of the solution alone can give only an imperfect criterion of the quantity of sugar present. Recourse is then had to the power which a solution of cane-sugar has of turning to the right the plane of polarized light. When therefore a liquid contains cane-sugar without any other substance possessing the same optical property, the quantity of sugar may be determined with great exactness by measuring the deviation which the liquid produces in the plane of polarization. To apply this method, the deviation must be known which is produced by a solution of sugar of known strength. For this purpose a given weight, ε, of sugar is dissolved in such a quantity of distilled water that the solution occupies a given volume, V. Sufficient of this solution is taken to fill a tube of a certain length, and the deviation suffered by the plane of polarization of the luminous ray passing through this tube is measured. Let this deviation be α. Let then other quantities of sugar be dissolved in sufficient water to give the same volume of solution, V ; and let the deviations produced by these solutions in the same tube be α' α' α''', *et cetera;* then the quantities of sugar contained in the volume, V, of these liquids will be represented by the products $\varepsilon\,\frac{\alpha'}{\alpha}$, $\varepsilon\,\frac{\alpha''}{\alpha}$, $\iota\,\frac{\alpha'''}{\alpha}$, *et cetera*, respectively. If the sugar examined, instead of being pure, is mixed with other but inactive substances, it is evident that these same products express the absolute weights of pure sugar contained in the weights of substances employed in the formation of the liquids of the given volume, V. It is possible to employ proof tubes of different lengths ; but it is then necessary to reduce by calculation the observed deflections to those which would have been produced in the same tube.

It often happens that solutions of sugar which have to be examined are turbid or strongly colored. When this interferes with the examination, they must be clarified and rendered either quite colorless, or when this is not possible the color must be at least reduced. This may generally be effected by precipitating the coloring matter of the sirups with subacetate of lead ; but at a sugar-work the most convenient and complete method is a filter of animal charcoal. The filtrates are then examined optically. When sirups contain, besides cane-sugar, other constituents which exert an action upon the plane of polarization, the amount of cane-sugar present may be often determined by inverting, by means of hydrochloric acid, the rotary power of the cane-sugar. No other saccharine substance is, in fact, known which suffers a similar change under the same circumstances.

If, for instance, the liquid under examination contains besides cane sugar, glucose, whose rotary action on the plane of polarization is in the same direction as that of cane sugar; if α' be the deviation observed to be produced by the liquid, then α' is evidently the sum of the separate deflections of the cane-sugar, x, and of the glucose, y. About one-tenth of its volume of hydrochloric acid is added to the sirup, and it is kept for ten minutes at a temperature of 140°–154°. The cane-sugar is thereby completely transformed into noncrystallizable sugar, which turns the plane of polarization to the left, while the rotary power of the glucose undergoes no alteration. When this change has been effected, the new deviation, α'', of the liquid is observed. It is now the difference between the deviation, y, of the glucose and that of the noncrystallizable sugar derived from the cane sugars. But the degree of dilution of the liquid having been changed by the addition of the hydrochloric acid, the deviation observed, α'', must be replaced by the deviation, $\frac{10}{9}\alpha''$, which would have been observed if the inversion could have been produced without the addition of hydrochloric acid. Admitting therefore that a quantity of cane-sugar which effects a deviation, x, gives rise to a quantity of noncrystallizable sugar which effects a deviation, $r\,x$, there is—

$$\text{Before the inversion, } x + y = \alpha'.$$

$$\text{After the inversion, } y + rx = \frac{10}{9}\alpha''.$$

From these two equations the quantities x and y may be determined. The coefficient of inversion, r, is determined once for all by a special experiment performed upon pure cane-sugar at the temperature at which the experiments have afterwards to be made. According to BIOT, this coefficient is 0·038 for hydrochloric acid at a temperature of 71·6°.

The process is the same when the cane sugar is mixed with noncrystallizable sugar, turning the plane of polarization to the left. In this case the initial deviation, α', of the liquid is the difference between the deviation to the right, x, of the cane-sugar, and the deviation, z, to the left of the noncrystallizable sugar. After treating with hydrochloric acid, the deviation, α'', is composed of the deviations of the original noncrystallizable sugar, and of that produced by the action of the hydrochloric acid. One then has—

$$\text{Before inversion, } x - z = \alpha'.$$

$$\text{After inversion, } z + r\,x = \frac{10}{9}\alpha''.$$

It is important in examining optically noncrystallizable sugar always to employ the same temperature, because a change of temperature materially affects the rotary power of this kind of sugar.

E. MAUMENÉ proposes chloride of tin—$SnCl_2\ 5\ HO$—as a reagent for sugar. By boiling he obtains a constant result. One part of sugar evaporated with fifteen to thirty parts of chloride of tin, and heated up to 220° or 226°, produces a brown body, insoluble in acids and alkalies. This he calls caramelin. It consists of $C_{12}\,H_4\,O_4$. Grape-sugar, cellulose, dextrin, and such bodies, give the same compound.

According to HORSLEY, alkaline chromate of potassa produces a green color in solutions of sugar, easily detected in a few drops.

FEHLING analyses sugar metrically in a beautiful way; but it is better suited to minute quantities than to the work of a sugar-house. He has a normal solution, made of—

40 grammes of sulphate of copper,
160 grammes of neutral tartrate of potassa, or 200 grammes of tartrate of soda,
700—800 grammes of caustic soda, specific gravity 1·12.
This is diluted with water to 1154·5 cub. c.

Of this solution 1 cub. c. = 0·0050 grape-sugar, or
0·00475 cane-sugar.

Grains may be used instead of grammes, and then 1 grain = 0·0050 grape-sugar, without change of calculation.

$$\left.\begin{array}{lll}\text{100} & \text{parts of} & \text{grape-sugar,....}\\ \text{95} & \text{“} & \text{cane-sugar, ...}\\ \text{90} & \text{“} & \text{starch, ...}\end{array}\right\} = 220\cdot5\ CuO, \text{ or } 198\ Cu_2O.$$

This mode is peculiarly valuable for urines, as it measures the smallest quantities. The urine should be diluted from ten to twenty times with water. It should be boiled a few seconds after adding each portion of copper solution. The sugar of urine is grape-sugar.

On the Manufacture of Cane-sugar.—The manufacture of sugar from the sugar-cane may be divided into five parts. 1. *The cultivation of the cane.* 2. *The extraction of the juice.* 3. *The purification of the juice.* 4. *Its concentration; and* 5, *its crystallization.*

1. *Cultivation of the Cane.*—The sugar-cane—*Arundo saccharifera*—is an indigenous plant of the gramineous family. Cultivators distinguish three great varieties—the Creole, the Batavian, and the Otaheite cane. The first is indigenous to India; but it has been transplanted to other soils, such as those of Sicily, the Canaries, the Antilles, South America, and the West Indies. It is known by its thin, very knotty stem, and green leaves. The Batavian cane is a native of Java, but is met with at present in some of the sugar plantations of the New World and the West Indies; it is covered with purple stripes, and has a heavy foliage. The Otaheite variety is spread over the West Indies and South America, and is esteemed by far the richer and more productive of the several species. There are besides, the purple-banded and the purple Otaheitian and the ribbon cane. The Bourbon is said to be the same as the Otaheite cane of Singapore.

The sugar cane in a state of maturity is usually from six to fifteen feet in length, and from one and a half to two inches in diameter. It is jointed, and the distance of the joints from one another is from three to seven inches. These joints correspond to the extremities of hexagonal cells of which the intermediate portions of the stem are composed, and which are in the living state of the plant filled with a solution of sugar. The exterior of the cane is smooth, hard, and cylindrical, and is covered with a coating containing a large quantity of silica. Germination occurs at the joints, and takes place at the opposite sides of alternate joints.

The sugar cane grows from pieces or slips of itself containing germs, and these develop rootlets at the joints, which draw sustenance to the young shoot as it increases. In the course of time the buds in the radicle, or root joints, of the first cane throw out roots, and form a radicle for a second stem; and in this way it happens, under favorable circumstances, that several canes are produced from the parent stock for a period of about six years, sometimes even for twenty years. From the first and second year, however, the canes diminish in the length of joint and circumference, and so the quantity of juice decreases; but it is alleged that the juice is much richer than when younger, and also produces a finer sugar. A common mode of obtaining successive crops is as follows:—When an old cane has been cut for its sugar, the incision is made some inches below the ground and the stump covered with mould. In about twelve months' time the offshoots from the original cane are ready for transplanting. In planting these slips or *ratoons* the system of wide planting is gradually superseding the old close planting. In addition to the advantage which the former kind offers in allowing the use of the horse-hoe for weeding, the great length of the root of the sugar-cane, which often extends laterally to a distance of six, and vertically to a depth of two feet, makes wide planting imperative, when rapidity of growth, as determined by quick absorption, is required. The cane holes are advantageously formed five feet from one another, in rows which are also five feet apart.

Of late years the system of cultivation of the sugar-cane has attracted considerable attention, as well in regard to the preparation of the soil as to the manner of planting. Formerly the custom of preparing the land by manual labor was followed; it is sometimes so still, and the consequence of not having the soil sufficiently disintegrated to the proper depth required by the plant, made itself apparent in the defective harvests of the plantations which followed; besides, by the practice of utilizing for fuel the *magass* or expressed cane, called *cane straw* and *cane trash*, instead of returning it to the land, the latter was rendered deficient in humus, and, therefore, not suited to retain the proper quantity of moisture, which, in the warm climates of its growth the cane absolutely requires for its proper development. And, although the ashes of the refuse might be consigned to the soil, yet this, instead of improving, rather defeated the objects which the cultivators had in view, as by the use of too much mineral matters as a manure, the sugar secreted by the plant was rendered uncrystallizable, and so, in a comparative sense, lost to the planter. An excess of soluble salts should always be guarded against in the cultivation of the sugar plant; but the fertilizer should be rich in humus and nitrogenous constituents, as the consumption of both these classes of bodies by the plant is greater in a much larger proportion than of mineral fertilizing matters. The knowledge of these facts has led to the desire of employing such matters as blood, decomposed flesh, rotten fish, wool refuse, and the like, for manure in the sugar plantations. Charred peat would, in the opinion of the Editor, be a valuable adjunct to such matters, as it would materially prevent evaporation of the natural moisture of the soil, and supply carbon to the growing plant. Another feature in the modern innovations on the old system of culture is, that the *ratoons* or *stocks* are planted much wider apart. Various parties differ in their views in this respect—some recommending the plants to be set four feet apart in rows six feet asunder; others recommend a greater distance between the rows, such as eight feet; while some state that this should be increased to ten, or that each *stock* ought to have a space allotted to it of six and eight feet either way from the next one. It is to be hoped that from considerations like these, of the necessity of pursuing a more rational course of tillage, the planter may, and he doubtless will, be led, in the course of a few years' practice, to adopt the mode which enlightened observation and study will show to be most advantageous.

The frequent droughts which occur in the countries adapted to the cultivation of the sugar plant, render the artificial prevention of the too rapid evaporation of the water, which would be very injurious to the freshly-planted ratoons, of the highest importance. The great bulk and solidity, and the richness in mineral constituents of the stem of the sugar-cane, would cause a rapid impoverishment of the soil, were not some adequate return made to it. Both purposes are effected by surrounding the stems of the newly-planted ratoons with the *megass* or cane from which the sugar has been extracted.

Canes require a well drained but still a rich and moist soil. Land with much saline matter is frequently found to prevent the canes ripening; they remain green and watery.

One variety greatly in cultivation in Jamaica came from Otaheite. When this cane is well cultivated, and in favorable soil, it rises in the first year to twelve or fourteen feet in height, being six inches in circumference, and having joints six inches apart. No field, however, will give an average so high as this. Plants such as these will produce two and a half to three tons of dry sugar per acre, but the average is considered good at two tons per acre. It sometimes attains maturity in ten months. Its foliage is of a pale green; leaves broad and much drooping, and flowering or arrowing in a manner graceful and ornamental. It requires a rich soil. The *yellow violet* may be put in poorer soil. It gives a fine sugar, but not so much as the Tahiti cane. It has a dark-green foliage. The juices of the two are frequently mixed. The *purple violet* is from Java, and is eight to ten feet high, and six inches in circumference. On the joints of the cane there is a large amount of a resinous film, which sometimes completely shades the purple beneath. This resin is very hard and troublesome to grind. The sugar of this cane is excellent. The cane itself is hardy, and is sometimes used in Jamaica as a border to other canes, defending them against the trespassing of cattle.

The large red cane of Assam is said to flower in eight months, and to give similar sugar to the Tahiti cane. In Bengal a large red cane is cultivated which gives excellent sugar. The China cane is said to be extremely hardy, standing both cold and drought, and, with abundant rain, giving out as many as thirty shoots. It resists the inroads of the white ants, which cannot penetrate its hard crust, whilst it is also safe against the teeth of the jackals. It requires, however, a stronger mill for grinding than the other varieties mentioned. Mr. **WRAY** asserts that the Salangore cane is the finest in the Straits of Singapore, and perhaps in the world. He says that he has cut five from one stool, which were of a weight of from seventeen to twenty-five pounds. They have been known to produce seven thousand two hundred pounds of undrained sugar per acre, equal to five thousand eight hundred of dry sugar for shipping.

Dr. **LIVINGSTONE** says that sugar is cultivated in the Shire valley, as well as many parts of Africa near the Zambesi, and may be had for as little as one half-penny per pound. There is field enough for great enterprise in that direction. The amount obtainable has not been investigated.

The time of harvesting the cane varies with the mildness of the season, the locality, the nature of the soil, and the variety of the cane cultivated. Generally a dry, smooth, brittle skin, a heavy cane, a grey pith, approaching to brown, and a sweet glutinous juice, indicate the maturity of the cane. A dry season is the time in which the canes should be cut, if possible, so that, by the absorption of too much moisture, the juice may not be diluted, and thus occasion increased trouble and expense in preparing the sugar from it. The canes are cut as close to the *stole* or root as possible, as well because the lower joints are found richer in sugar, as to give vigor to the ratoons, which are to spring from the old stock; the tops, with one or two joints, if they be not sufficiently ripe, are cut off, and the canes tied in bundles, and conveyed to the crushing mill. It is absolutely necessary that the cane be cut just before expressed in the mills; for, if allowed to remain any length of time at the high temperature of the climate, the sugar ferments, and a considerable loss is consequently occasioned.

Dr. **EVANS** gives the products of an acre of canes in Barbadoes as—

Weight of canes.	Weight of juice.	Extract.	Extract per 100 pounds of juice	Extract per 100 pounds of canes
30 tons.	60,480 lbs.	10,886 lbs.	18·0	16·20
30 tons.	47,040 lbs.	8467 lbs.	18·0	12·6
30 tons.	33,600 lbs.	3500 lbs.	10·0	5·0
30 tons.	33,600 lbs.	7280 lbs.	21·6	10·8

An acre may be said to yield thirty tons of canes. The following table gives the produce in juice and sugar:—

Juice obtained per cent.	Juice in pounds.	Pounds of Sugar.			Subtract for Molasses and Skimmings, at 12 per cent.			Pounds of dry Sugar yielded by one Acre.		
		At 18 per cent.	At 20 per cent.	At 22 per cent.	At 18 per cent.	At 20 per cent.	At 22 per cent.	At '8 per cent.	At 20 per cent.	At 22 per cent.
70	47,040	8,468	9,408	10,348	705	792	862	7,763	8,616	9,486
75	50,400	9,092	10,080	11,088	757	840	924	8,335	9,240	10,164
80	53,760	9,676	10,752	11,827	806	896	994	8,871	9,856	11,173

This supposes the juice to stand at 10° Beaumé; at the same time all the numbers given are above the amount actually obtained in practice, which does not appear to be above five thousand pounds per acre.

But it is difficult to tell the real amount of sugar obtained on the estates. The books on the subject are frequently very one-sided, or very confused, or they are not possessed of the information except for certain estates. Perhaps four thousand pounds of sugar and one hundred and seventy gallons of rum, twenty per cent. over proof, is a very fair specimen of the yield.

The following table by M. **DUPREZ** is given by Dr. **EVANS**. The average amount of juice from one hundred pounds of canes was—

1. By mills having horizontal rollers—motive power not stated—probably steam	61·2
2. By mills, motive power steam	60·9
3. By mills, motive power wind and steam	59·3
4. By mills having vertical rollers	59·2
5. By mills, motive power cattle	58·5
6. By mills, motive power wind	56·4

but 70 can now be obtained by greater power, and some speak of 80.

Of the eighteen to twenty-two per cent. of sugar in the cane, it is generally believed that no more than eight is obtained crystallized.

If only fifty per cent. of the juice is taken from the plant, and thirty still remain in it, three-eighths of the sugar are taken away in the megass and burnt as fuel. Sugar must be to the planter at least worth twenty pounds per ton, whereas he could get coals from England at one pound. But this would not be an important loss, it is said, if the ashes of the megass were only taken and thrown on the soil, as was shown by Dr. **STENHOUSE**. The climates which grow sugar grow ligneous fibre rapidly, and it is well to use it for fuel when it can be obtained. The ground, however, must not be deprived of its inorganic constituents. It is also important to use the megass early, as the sugary matters unavoidably left in it oxidize, and, of course, give less heat in burning. It is well, however, to burn as little sugar as possible, at the same time to avoid an excess of soluble salts.

The following tables are from **PAYEN**:—

OTAHEITE CANE AT MATURITY.

	Centesimally.
Water,	71·04
Sugar,	18·00
Cellulose, ligneous matter, pectin, and pectic acid,	9·56
Albumen and three other nitrogeneous matters,	0·55
Cerosin, green matter, yellow coloring substance, substance capable of being dyed brown, and carmine, fatty matter, resins, essential oil, aromatic matter, and a deliquescent substance,	0·37
Insoluble salts 0·12; soluble 0·16; consisting of phosphates of lime and magnesia, alumina, sulphate and oxalate of lime, acetates, malate of lime, potassa, and soda, alkaline chlorides, and sulphates,	0·28
Silica,	0·20
	100·00

CANE ONLY AT A THIRD OF ITS DEVELOPMENT.

	Centesimally
Water,	79·70
Sugar,	9·06
Cellulose and incrusted ligneous matter,	7·03
Albumen and three otber nitrogeneous substances,	1·17
Starch, cerosin, green matter, yellow coloring substance, and bodies colorable to brown and carmine,	1·09
Fatty, aromatic, and hygroscopic substances, essential oil, soluble and insoluble salts, alumina, and silica,	1·95
	100·00

The fresh cane has been estimated to contain—

	Tahiti Per cent.	Cuba. Per cent.
Water	72·1	65·9
Ligneous fibre	9·9	16·4
Sugar and other substances	18·0	17·7
	100·0	100·0

The juice of Martinique cane has been found to contain—

Sugar	20·9
Water	77·2
Organic substances not sugar	0·2
Inorganic salts	1·7
	100·0

The megass or residue, after passing the rollers—

Sugar	7·9	7·3
Molasses	3·0	2·7
Ligneous matter and earthy salts	38·6	39·5
Water	50·5	50·5
	100·0	100·0

Casaseca has analyzed the Havana cane — the *creole*—and found—

	Cane entire.	Cane peeled.	The rind
Water	77·0	77·8	69·5
Sugar and soluble substances	12·0	16·2	11·5
Ligneous matter	11·0	6·0	19·0

He says that 23 of dry cane contain 12 of sugar, and 23 of the dry rind only 8·6.

The amount of water in the sugar-cane increases according to Casaseca, towards the top; the greatest amount of sugar is found in the lower third of the cane, but much less in the upper part; the centre third contains about an average of the whole. The water even of the joints increases on rising.

The pure or nearly pure juice, when the green matter is removed, contains—

	Per cent.
Water	81·00
Sugar	18·20
Organic matter, precipitated by lead salts	0·45
Saline matter	0·35
	100·00

Cane juice has a specific gravity of 1070 to 1090—10° to 13° Beaumé. It has been obtained as low as 1046, and as high as 1110, at 80° Fahr. It is opaque, frothy, and of a yellowish green. The green part may be filtered out, leaving a pale yellow fluid, which is almost pure sirup. The green scum consists of chlorophylle, cellulose, ligneous fibre, and albumen. Its analysis given by Avequin is—

	Per cent.
Cerosie—a peculiar wax	50·0
Green matter	10·0
Albumen and ligneous fibre	22·7
Phosphate of lime	3·3
Silica	14·0
	100·0

A gallon of juice, weighing about ten and three-quarter pounds, contains about twenty-seven grains of this greenish scum.

Mulder believes that the light-colored sugars contain most cane-sugar generally. He also says that the many varieties into which sugars are divided in Holland are not well based.

Mulder gives the following analyses of several raw sugars :—

	Cane sugar.	Grape sugar.	Water.	Ashes	Water of the insoluble part.	Remainder—caramel, gum, and acids
Ten sorts of Java	98·6 — 83·1	5·5 — 0·3	6·1 — 0·3	1·9 — 0·2	0·2 — 0·0	3·5 — 0·5
Six sorts of Havana	97·0 — 87·3	3·7 — 0·9	3·5 — 0·9	1·1 — 0·0	0·3 — 0·0	4·5 — 0·4
Four sorts of Surinam	92·3 — 85·4	4·4 — 1·6	6·3 — 3·6	1·4 — 0·8	0·6 — 0·4	2·1 — 1·1
Pure candy	99·6	0·1	0·2	0·1	—	—
White sugar	99·7	0·2	0·1	—	—	—

Twelve kilogrammes of molasses of cane sugar contain according to Payen—

Sugar	7·561·00
Acetate of potassa	0·209·30
Chloride of potassium	0·114·60
Sulphate of potassa	0·085·50
Mucilaginous matter	0·076·30
Phosphate of lime	0·052·00
Nitrogenous substances	0·050·00
Silica	0·023·90
Acetate of lime	0·016·20
Phosphate of copper	0·000·20
Water	1·800·00
Glucose and uncrystallizable sugar	1·561·00

Richardson found sugar and the molasses from it to contain—

	Sugar.	Molasses.
Potassa	19·42	36·23
Lime	14·67	12·72
Magnesia	10·72	11·14
Oxide of iron	6·55	2·62
Oxide of copper	0·71	trace of both
Protoxide of manganese	trace	
Chloride of potassium	8·03	1·58
Chloride of sodium	15·46	25·87
Sulphuric acid	10·85	7·91
Silica	13·59	1·93
Ashes	1·33	3·60

A few, out of many analyses made by Dr. Stenhouse of the ashes of the cane, may be given—

Silica	46·46	41·37	46·48	50·00
Pbosphoric acid	8·23	4·59	8·16	6 56
Sulphuric acid	4·65	10·93	7·52	6·40
Lime	8·91	9·11	5·78	5·09
Magnesia	4·50	6·92	15·61	13·01
Potassa	10·63	15·99	11·93	13·69
Soda	—	—	0·57	1·33
Chloride of potassium	7·41	8·96	—	—
Chloride of sodium	9·21	2·13	3·95	3·92
	100 00	100·00	100·00	100·00

Refuse of sugar has been analyzed by—

	Prof Johnston.	Dr Anderson.
Water	60·26	48 44
Organic matter—refuse blood and sugar	20·77*	39·10*
Phosphates of lime and magnesia	8·67	3·97
Lime	3·55	3·41
Magnesia	—	0·19
Common salt sulphates of potassa and scda	0·77	1·64
Insoluble silicious matter and sand	5·98	3·23
	100·00	100·00
* Containing ammonia	1·06	2·23

Blood is now less used, and a refuse like the above would not now be easily obtained.

The feculencies of the sugar obtained by defecation, without the addition of lime, or indeed of anything but water, were found by Mr. Thornton J. Herapath to contain 13·574 parts of ashes, composed of—

	Per cent.
Water	48·940
Organic matter	37·486
Carbonate of potassa	0·146
Sulphate of soda	0·155
Chlorides of sodium and potassium	0·237
Carbonate of lime and some carbonate of magnesia	3·964
Sulphate of lime	1·231
Phosphate of lime and some phosphate of magnesia	2·679
Phosphate of iron and alumina	1·320
Silicions residue insoluble in acids	3·842
	100·000

The dry substance contained .... 5·42 per cent. of nitrogen.
Undried .... 2·82 " "

The prepared sugar is very pure. Mulder found in one hundred parts of dry sugars—

	Water given off at 212°.	Ashes.	Grape-sugar.
Five kinds of candy sugar	0·011 — 0·475	0·0 — 0·104	0·132 — 0·192
Four kinds of white sugar	0·071 — 0·100	0·03 — 0·735	0·134 — 0·239
Four kinds of common sugar	0·121 — 0·225	0·052 — 0·152	0·230 — 0·365

It is found that sugar which is brought over in iron vessels, frequently oozes out and attacks the iron, doing injury to the vessel. Iron is rapidly dissolved by sugar. The sugar may become a little acid and then attack the iron, but it soon throws it down again as an oxide, as Dr. Gladstone has observed, and thus a small amount of sugar destroys a large amount of iron. Dr. Gladstone obtained the following compound:—

	Found.	Calculated.
Protoxide of iron	17·20	17·39
Sugar	82·80	82·61

Sugar readily decomposes a sesquioxide of iron in solution into a protoxide. Dr. Gladstone did not find that zinc prevented the oxidation of the iron. Zinc itself is not easily separated from sugar. Copper is scarcely acted on by sugar, but the oxide is dissolved, and lead is dissolved in no small quantities. This corroding power is not known to belong to pure crystallizable sugar, and the experiments of the above chemist must be taken as referring to the molasses, *et cetera*, united with it.

From the analyses on page 972 may be learned the absolute necessity of permitting the caue to attain its full growth and maturity before being cut for the extraction of its secreted sugar; and further, that in the system of manufacture in some cases adopted, the exhaustion of the cane is so imperfect as to leave fully one-half or three-eighths of its juice in the straw; thus, at the very first outset, causing a loss to the planter or sugar-maker of about one-half the quantity which the cane contains. When the other defects of the manufacture are considered as tending to convert the crystallizable into uncrystallizable sugar, producing fermentation and oxidation, the clue to the enormous waste in the manufacture of sugar is at once obtained. These losses may be grossly set down as being due—

To imperfect extraction of the juice	45 to 50 per cent.
To transformation to uncrystallizable sugar, *et cetera*	12·5 to 15 "
Loss of crystallized sugar	57·5 to 65 "
Balance, or quantity of sugar obtained	42·5 to 35 "

2. *Extraction of the Juice.*—The sugar exists in the cells of the cane in the state of solution, which constitutes the juice or sap of the plant. Analyses have shown that the quantity of juice and its richness in sucrose, are variable to some extent; but on an average the per-centage of sugar amounts to seventeen or eighteen parts in good cane. The following additional analyses indicate an average composition—

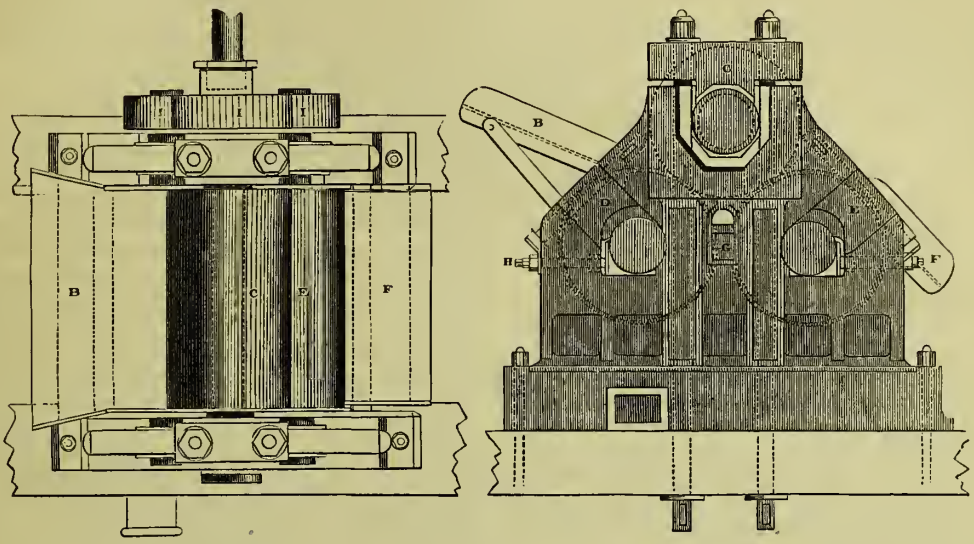
	Centesimally.		
	From Martinique, by Peligot.	From Guadaloupe, by Dupuy.	From Cuba, by Casaseca.
Water	72·1	72·0	65·9
Sugar	18·0	17·8	17·7
Ligneous matter	9·9	9·8	16·4
Salts	—	0·4	—
	100·0	100·0	100·0

Such also is the average composition of the cane of the third, fourth, and succeeding years' growth from the parent stock, as shown by Peligot's researches on this subject. Hervey examined two specimens of sugar-cane of Guadaloupe, and the megass which they yielded. The samples were grown on two different soils—No. 1 being produced by a dry, calcareous, and elevated one; and No. 2, by a low soil in the neighborhood of volcanic eruptions. The following are his results calculated without water:—

	No. 1.		No. 2.		
	Sugar-cane.	Megass or Straw.	Cane Sugar.	Megass or Straw.	The same brown and decomposed.
Sugar	64·6	22·5	67·0	29·2	42·4
Extractive matters	0·3	—	0·3	—	—
Wax	0·9	1·8	1·2	1·6	1·6
Soluble salts	0·3	1·8	1·2	2·4	3·3
Insoluble salts	1·0		1·3		
Ligneous matter	32·6	73·9	28·9	66·8	52·7
Loss	0·3	—	0·1	—	—
	100·0	100·0	100 0	100·0	100·0

The saccharine liquid is extracted from the cane by pressure. The sugar-mills employed for this purpose are chiefly three, namely, the horizontal and the vertical roller mill, and the hydraulic press. The latter, however, has not received general adoption. The accompanying woodcut—Fig. 554—shows the construction of horizontal sugar mill.

Fig. 554.



The vertical mill, in which the crushing cylinders are placed vertically, has the advantage of being more easily cleaned; but it is less easily fed, and is more costly in its construction. A great deal depends upon the right adjustment of the distances of the three rollers, a too near approximation causes, on the one hand, an increased expenditure of force in the working of the mill, and on the other, a too great distance allows a portion of the juice to escape extraction, and to be carried off in the megass. The distance between the feeding roller and the upper one is about half an inch; the delivering roller is still closer to the upper one. In feeding a horizontal mill, the canes are cut into lengths of about three feet, and so spread upon the feeding board that these may overlap one another as little as possible. Mills have also been constructed with five and with four rollers. When five rollers are employed three are placed below and two above. A five-roller mill is said to extract ten per cent. more juice from the cane than a three-roller one; but the megass is thereby much broken, and a much greater expenditure of mechanical power is required to work the mill. In the four-roller mill, where two rollers are placed below and two above, while a greatly superior amount of juice is obtained, the expenditure of force is said to be not much greater than in the ordinary three-roller mill; hence it is probable that the four-roller mill will gradually supersede those now generally in use.

Some years ago a method was patented by Mr. Michiel for extracting the sugar from cane without the use of the mill; it was proposed to cut the canes into thin slices and treat them with lime water. The object of this was to render the nitrogenous constituents of the cane insoluble. On treating the so-prepared canes with water, a sirup is obtained of a purity much greater than that obtained directly by mechanical means. Probably the mechanical difficulty experienced in slicing the canes has prevented the adoption of this method. The following are the experiences of Dr. Evans—given in the Sugar Planter's Manual, published in 1857—in regard to the advantageous working of a sugar mill:—1. The rollers should be approximated as closely as the work which they have to perform will admit of. In mills in which the rollers observe a vertical direction, the space between the first and second should scarcely, if at all, exceed a quarter of an inch, whilst a distance of one-sixth of an inch is the most that should be allowed between the second and third. When they are placed horizontally, the upper one should be distant a space of one-fifth to a quarter of an inch from the two lower. 2. The velocity of the rollers should be rendered as uniform as possible, not by diminishing the amount of the motive power, but by a carefully regulated supply of canes. 3, 4. The megass should be invariably repassed between the rollers so as to extract as much as possible the juice which still remains in it. When canes are rich, and their juice of considerable density, the megass should be sprinkled with a little water, or, where it is practicable, exposed to the action of steam before it is submitted to the pressure; but when the canes are large, green, and watery, this may be dispensed with.

The amount of juice obtained from the cane is not always a criterion of the comparative yield in sugar. The drought or humidity of the season preceding the cutting of the canes determines the presence of a less or greater amount of water in the cane, while the quantity of sugar remains for a time unaffected. Between moist and dry seasons, and thorough and imperfect crushing, the yield of juice may vary from fifty to seventy-five per cent. of the weight of the canes employed.

The following table shows the proportions of the solid constituents—other than sugar—in cane juice. The relation of these amongst one another is probably pretty constant, although the quantity of sugar and of water may vary much with the age of the plant and the season at which the juice is extracted.—*Ure.*

One hundred parts of solid constituents contain—

Sulphate of potassa,	11·3
Phosphate of soda,	10·2
Chloride of potassium,	5·3
Acetate of potassa,	40·6
Acetate of lime,	22·9
Silicic acid,	9·7
	100·0

The methods employed in Hindostan and Ceylon for the extraction of the sirup or *goor* from the cadgoolee and other species of indigenous cane are so imperfect as to require no special description.

Captain MARGETSON, R.N., has proposed to cut the cane in pieces, and dry it as beet-root is dried, sending the substance home for the extraction of the sugar. This is a very promising field of inquiry.

3. *The Purification of the Sirup.*—The removal of impurities from the juice, as it is delivered from the mill, may be divided into two processes, defecation and clarification.

The crude cane juice contains, besides sugar and water, the impurities—earthy insoluble particles, fragments of the crushed cane or megass, albumen, caseine, wax, soluble coloring matter, and soluble salts. The coarser of the insoluble particles are sometimes removed mechanically previous to the process of defecation. But certain of the nitrogenous impurities of the crude juice if left in contact with the sirup speedily determine its fermentation, thereby occasioning loss in sugar, and owing to the subsequent conversion of the alcohol generated by fermentation into acetic acid, causing the corrosion of the metallic portions of the machinery, and the introduction of metallic acetates into the sugar. It is of the greatest importance that the process of defecation, whereby the nitrogenized compounds are removed, should follow with as little delay as possible upon the extraction of the juice. For this reason the storing of the sirup in tanks until a sufficient quantity is obtained for purification, is to be reprehended. The first filtration also should, for the same reason, be performed as rapidly as possible. This filtration is effected through a double sieve, the metallic meshes of the first sieve being about one-twelfth, those of the lower about one-thirtieth of an inch asunder. The sirup is run from these sieves, or directly from the crushing mill, through a wooden gutter lined with lead to the clarifiers. These are a series of copper cauldrons capable of holding from three thousand to four thousand gallons each. The bottoms of the clarifiers are usually concave, being bulged inwards from below. Each cauldron is provided with a separate fire, the flues from which run into a common chimney, and each fire is provided with a separate damper for regulating or stopping the draught.

Defecation.—When this is performed in the Colonies, the sugar is boiled down from the strength of 10° Beaumé only to about 27° or 28°, which is the strength suited for hot filtration. When it is performed in England, the sugar is dissolved in water, so as to be of the strength of 27° Beaumé.

Lime is the agent most frequently employed in defecating the sirup; but considerable differences of opinion exist concerning the best method of its application. The lime should be thoroughly burned and quickly slaked with hot water, enough water being added to give the consistence of a cream. This should be then filtered through a fine wire sieve in order to remove silicious particles and fragments of unslaked lime or unburned limestone. Some sugar manufacturers adopt the following process:—When the sirup in the clarifiers has attained the temperature of 130° Fahr. successive portions of the cream of lime are added, until the acids in the sirup—acetic and lactic—have been completely and exactly neutralized, which is shown by its neutrality to blue and red litmus paper. The mixture of sirup and lime is thoroughly incorporated with an oar, and the whole left to digest for about a minute. The portions of cream of lime successively added to effect neutrality should not contain more than about four ounces of solid lime per gallon. The product so obtained is run off through a stop-cock in the clarifyer, either through bag filters or through charcoal filters, subsequently to be described. In the more common process of defecation, however, after neutralization by cream of lime, as above described, the heat is urged until a temperature just below the boiling point of the sirup is reached. A thick scum is then formed upon the surface of the sirup, and the clarification is judged complete when this scum breaks and a white froth appears in its interstices. In all cases an excess of lime is to be avoided, partly because nitrogenous matter, upon the removal of which, from an acid solution by heat and lime, the clarification in a great measure depends, is redissolved by an excess of this agent, but mainly because of the destructive action of caustic earths on sugar. If, however, an excess of lime has been added, it may be remedied by the addition of small quantities of a solution of alum. When this salt is added to any alkaline solution with excess of lime, its alumina is precipitated and rises with the same, fixing a portion of the coloring matter of the sirup at the same time, and thus assisting in the clarification. Of the simultaneous products found in this reaction, *videlicet*, sulphate of lime and sulphate of potassa, the first is in a great measure insoluble and rises with the scum; the second, however, is soluble in the sirup, and cannot be subsequently separated from it; and this is the only drawback in the employment of alum to neutralize overlimed sirup. Sulphate of alumina, however, is not subject to this disadvantage, and may, therefore, advantageously replace alum in the neutralization of overlimed sirup.

Other substances have been employed for the defecation of cane juice, of which the principal are bullock's blood, nut-galls, sulphate of zinc, alum, sulphate of alumina, sulphuric acid and lime, and subacetate of lead. As bullock's blood is almost exclusively employed in the defecation of beet-root sugar, its application will be described under that head.

Nut-galls. — After the clarification by means of cream of lime of four hundred gallons of sirup has been effected, the temperature is raised to 150° or 160°, and a decoction of nut-galls is added, formed by digesting two ounces of the bruised galls in half a gallon of boiling water. The mixture is stirred for two or three minutes with an oar, boiled and strained through bag filters.

Sulphate of Zinc.—Twelve ounces of sulphate of zinc are added to a clarifier of three hundred gallons. The sirup is then neutralized with cream of lime, boiled and filtered.

This process has not been used, as it is difficult to remove the taste of the zinc.

Alum.—Four pounds of alum in solution are added to a clarifier of three hundred and fifty gallons; as it begins to get warm the heat is rapidly raised to 140°, and the sirup neutralized with cream of lime.

Alum should never be used, as it introduces salts of the alkalies, which cannot be removed.

Sulphate of Alumina.—A pound of sulphate of alumina is added to every hundred gallons of juice, and the whole quickly neutralized with lime and filtered as before; still not of much value.

Ammonia has been proposed as an addition to sugar, especially to beet-root juice; but its value has not been shown.

Alumina and Sulphate of Lime.—The alumina obtained from two pounds of alum by precipitation along with sulphate of lime, by means of carbonate of lime in suspension, is washed by decantation and added to one hundred gallons of cane juice. When the temperature of the sirup has reached 150°, lime is added to neutralization and the juice is then filtered.

Sulphuric acid diluted with thirty times its volume of water is added to the sirup—for three hundred gallons of the latter, two fluid ounces of sulphuric acid are employed—at a temperature of 120°; four ounces of lime are then added, and when the temperature reaches 170°, the sirup is neutralized with more lime and filtered.

The value of this method is extremely small.

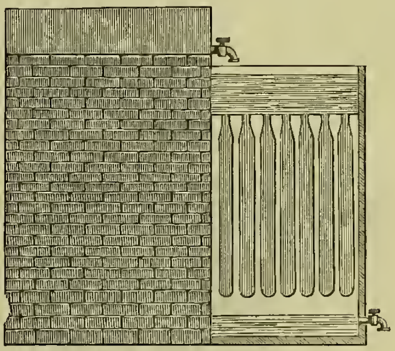
Subacetate of Lead.—It has been proposed to effect the defecation of the sirup by the successive employment of subacetate of lead and phosphate of lime. Subacetate of lead has the power of throwing down the whole of the coloring matter and other organic foreign substances present in the sirup. But the subsequent separation of the lead which is in solution by phosphate of lime, is either not perfect in the presence of sugar, or requires more delicate manipulation and greater care than can be usually looked for in sugar manufactories. The deleterious action of repeated though very minute doses of lead on the system has prevented its employment as a defecating agent.

Dr. Scoffern precipitates the lead by sulphurous acid, and by this means it is found that he can remove it all; but the dangers attending the use of lead are so great, that his process, although beautiful when done well, and perfectly capable of being done well, has been discouraged if not prohibited, and the plan will therefore probably be abandoned. Man's constant accuracy cannot be trusted. *Tin* has been tried, but is not practically found useful.

When the scum has risen to the surface, and the clear sirup is seen through its cracks, the approach of which point is usually judged of empirically by the thickness of a portion of the sirup removed from the clarifier, and by the equalization in size of the bubbles formed in the liquid, the defecation is complete. The defecated sirup is then removed from the scum by tapping, or the latter is removed from the sirup by skimming, in both cases sufficient time being allowed for the heavier portions of the scum to subside. As the scum always contains a considerable portion of sirup in its pores, it is generally submitted to pressure in a simple lever press, and the extract added to the liquid which has been tapped off. Fig. 555 shows the usual form of the clarifier.

In those countries where fuel is cheap, and especially in those manufactories where steam is employed, either as a motive power for the mill, or the vacuum pan—afterwards to be described—or for other purposes, the heating of the clarifier is sometimes effected by means of steam. It is clear that as the temperature requisite for boiling in the open air is above that of boiling water, the steam by which it is effected must be either overheated or high pressure steam. And as in most sugar growing lands fuel is scarce, and as a great use of fuel attends the application of overheated steam, high-pressure steam is employed. This is usually conveyed by a copper worm through the clarifier, the steam passes downwards round the spirals of the worm, and the condensed water is discharged under pressure.

Fig. 555.



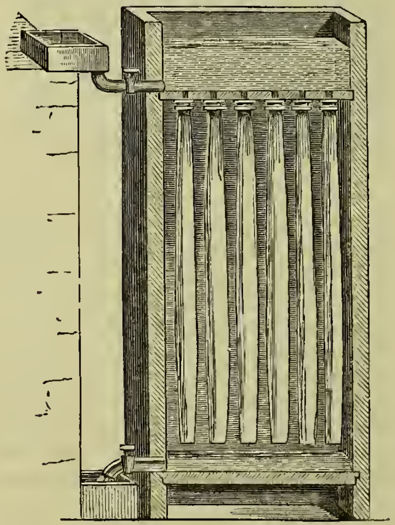
Simple Filtration.— The process of defecation always leaves impurities in the sugar, either in the form of suspended scum, or when filtration is not performed previous to the defecation of the mechanical impurities formerly mentioned. In all cases it has now to undergo another filtration.

It is usual to run off the sirup at once from the clarifyers upon the filters, and the preceding diagram shows the simplest arrangement for this purpose. The matter of the filter is always cotton. Woollen textures are rapidly destroyed by the alkaline nature of the scum. The forms given to the filters are chiefly two —the leaf-filter of LOVERING and the bag-filter of TAYLOR.

The leaf-filter is composed of a series of cotton bags stretched over thin quadrangular frames, which keep the sides of the bags apart, and cause them to present a smooth even surface instead of folds, thus greatly facilitating the operation of cleaning, when it has to be performed. These frames are arranged side by side in a box, and the juice which filters from without inwards, escapes by a hole in the bottom of the frame. The juice is poured into the box outside of the frames, and the filter, therefore, is not clogged by impurities as readily as TAYLOR'S filter, in consequence of which it works more rapidly and does not require to be cleaned so often.—*M'Culloch.*

TAYLOR'S bag-filter—Fig. 556—consists of a number of cotton bags about two feet in length and a foot in diameter when fully extended. Into their narrow mouths the nozzles of the tubes pass which deliver the sirup. The bags are fastened on the nozzles by means of a sliding ring. Each bag is inclosed in a cylindrical one of canvass about four inches in diameter, the object of which is to prevent the swelling out of the interior cotton filter. In such a filter of course the interior bag is much folded; nor can it in this state present the same amount of filtering surface as it would were it fully inflated. It may indeed be questioned whether with tolerably clean sirup such a folded filter offers much advantage above a filter of the size and shape of the exterior canvass bag.

Fig. 556.



When the leaf or bag filter has become choked it must be washed; this is sometimes done by machinery. The use of very dilute hydrochloric acid or of acetic acid facilitates the washing, by dissolving the lime in the scum. But the first acid at least, however dilute, weakens the cotton fabric when often applied, and the presence of every acid should, when possible, be avoided in every process of sugar manufacture; because the vinous fermentation to which all saccharine liquids are liable is found to be facilitated by the presence of any acid.

Charcoal Filtration.—The previously described processes of filtration and defecation effect the removal of the mechanical impurities in the sirup, as well as those albuminous and nitrogenous substances which are solidified by the heat of the clarifiers, and removed in the scum which is formed in them. But besides such impurities, the juice of the sugar cane contains various coloring matters whose chemical nature has not been examined, and which are not removed either by filtration or defecation —except where, in the latter process, subacetate of lead is employed. As these coloring matters do not separate by the further evaporation of the sirup, but obstinately remain with it, a further process of decolorization is necessary before the final evaporization is effected. Animal charcoal is the agent employed for this purpose. When the bones of animals are subjected to dry destructive distillation, without access of air, the residue consists chiefly of carbon, and the phosphates and carbonates of lime, with a little of the same salts of magnesia. Such charcoal possesses pre-eminently the power of removing many organic substances from solution when brought into prolonged contact with the liquids which contain them. Thus strychnine when in solution is removed by agitation with animal charcoal. The decolorization of sugar depends upon the same power of animal charcoal. Animal charcoal or bone-black, in removing coloring matter from sirup, undergoes no profound change. It appears to act by a species of superficial affinity; that is, as far as the process can be followed, an affinity that pervades the surface of every one of the minute pores of the charcoal, rendering the actual superficies enormous. But although the charcoal thus remains unchanged, its decolorizing power is so far limited, as when its surface becomes too thickly covered by the coloring matter it withdraws, a charcoal surface is no longer presented to the liquid.

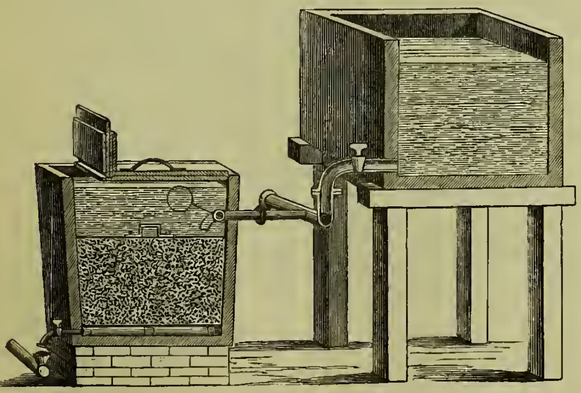
The bone-black preferred by sugar manufacturers for the decolorization of sirup is that obtained from the larger bones of animals—as the thigh and shoulder bones of oxen. This variety is generally not only more compact than that obtained from the smaller bones, or from the bones of smaller animals, but appears to possess a specifically greater decolorizing power. Such bones after burning are reduced to a coarse powder, the grains of which are about the size of small peas. In some manufactories, however, where the process of defecation and decolorization are united, and where powdered bone-black is added to the sirup in the clarifier, the bone-black is employed in a finer state of division, the grains being then of the size of those of the finest gunpowder. But as in this method the bone-black employed is thrown up with the scum in the clarifier, mixed with the salts of lime and other feculences from which it cannot be separated, it is lost, and consequently the application of bone-black in the clarifier is seldom adopted. The decolorization by filtration through bone-black is generally effected immediately after the filtration through the cotton filters above described. The following description of the two kinds of bone-black filters most frequently employed abroad, but now scarcely used here, is from R. S. M'Culloch's report.

Dumont's filter consists of a wooden box of the form of a four-sided truncated pyramid with a double bottom. The inner bottom is a metallic plate pierced with numerous holes; upon it a cotton cloth is laid, and coarse-grained animal charcoal moistened with water is then spread layer by layer; each layer being rendered of uniform thickness, and packed or pressed closely together by means of a sort of trowel. When the bone-black has been thus formed into a compact bed or stratum of about fifteen or eighteen inches in thickness, and within five to ten inches from the top of the box, it is covered with another cotton cloth, and with another metallic plate pierced with holes. The object of the second cloth and metallic cover is to collect any substances which would otherwise obstruct the interstices of the superior stratum of the bone-black—an inconvenient accident which is easily prevented by the use of such a cover, and this cover is readily exchanged for another, should it become itself obstructed. The superior cover is only of use when the previously described filtration through the cotton bag or leaf filter is omitted.

It is important, in order to avoid false passages, that the juice should be constantly at the same level of about three or four inches above the cover of the bone-black. This is accomplished by means of a self-regulating cock.

To facilitate the action of Dumont's filter—Fig. 557—the bone-black must be perfectly free from fine powder, which would obstruct the passage of the sirup, and thus retard its flow. To render it so it should be carefully sifted each time after revivification.

Fig. 557.



Peyron's filter is another form of metallic filter to be used like that of Dumont's with coarse bone-black. It is intended, however, to act continuously and without renewal of the bone-black. This filter is cylindrical, in height eight feet, and in diameter thirty-nine inches. The top is closed with a perfectly air-tight cover, and the vacant space of the double bottom communicates by a tube and cock with the top of a second and smaller filter, so that the sirup which has filtered through the first passes through the second, from which, in like manner, it proceeds through a third. The closed top permits the use of hydrostatic pressure to increase the rapidity of filtration, and the juice enters the first filter for that purpose by a tube from a reservoir above. The double bottom of each filter of the series is also provided with another outlet and stop-cock to permit the fluid contents to be drawn off at any time, if desired.

The filters of Peyron, like those of Dumont, are charged with coarse bone-black, carefully compressed in layers; after which the fine powder is washed out thoroughly with water, and when this flows perfectly clear the sirup is allowed to pass into the filter, and to remove the water by *displacement*. As soon as the water which escapes from the double bottom is sweet to the taste, it is collected in the reservoir to be evaporated. After the sirup ceases to flow freely, hot water is used to displace that portion absorbed by the bone-black; and as soon as the density of the escaping liquid becomes feeble it is no longer collected. The hot water is then allowed to flow through the filters until they are washed perfectly. Fermentation soon commences in the filter by reason of the dilute sirup and nitrogenous impurities absorbed by the bone-black; and after twenty-four hours, when the fermentation is considered complete, and the impurities taken up by the bone-black are thereby destroyed, the filter is cleaned to prepare it for work a second time, by first passing through it for half an hour a jet of high-pressure steam, and subsequently washing it thoroughly with hot water.

Another form of filter somewhat similar to Peyron's is as follows:—A series of four cylindrical boxes, provided with perforated false metallic bottoms are connected together as before with stop-cocks in such a manner that each may be removed without disturbance of the rest. If they are all charged with fresh bone-black, and the sirup is run through until it begins to become colored, it follows that the charcoal in the upper boxes must have lost its decolorizing power to a greater extent than that in the lower ones. The highest box is therefore removed; the next highest becomes now the highest, the third becomes the second, and so on—a box of fresh charcoal being introduced below. In this manner the filtration may be carried on with but little interruption for any length of time. To insure the uniform distribution of the sirup upon the upper layer of the box, a mechanical contrivance is sometimes employed. This is of the form of a horizontal tube, perforated with holes throughout its length, but closed at its ends, and capable of revolving with facility about its centre. The passage of the sirup through the tube and through its orifices determines the revolution of the tube about its axis, and the consequent distribution of the sirup upon its surface.

The filters on the Continent are still frequently of this kind, but such are seldom used in England, where it has been found economical to use them of enormous size, being about thirty feet in height, and four to eight feet in diameter. A filter like this contains about twelve tons of animal charcoal. Charcoal is expected to purify, on an average, an equal weight of fine, or twice its weight of *seconds* sugar.

The same bone-black may be employed any number of times, provided the substances which it has withdrawn from the sirup be removed. This is sometimes done by allowing them to ferment, as in PEYRON'S filter; but more frequently by simple rekilning. The kiln made by G. F. CHANTRELL of Liverpool for the revivification of the bone-black is seen in Fig. 558. Those of PONTIFEX and WOOD and others are under the article *Charcoal.*

Perhaps no part of a sugar refinery is more important than the burning of the charcoal or bone-black. This is generally used in small pieces, the largest about the size of a half pea, and slightly elongated in the direction of the length of the bone from which they are formed. It was at one time usual to grind the charcoal to dust, but this habit is now almost entirely given up. When fine the sugar does not run so rapidly through the filter, and it is not mixed with so much facility or so much convenience; besides, it is not so easily burnt or revivified. In general, too, refiners object to the very fine charcoal, and either drive it off by blowers when the charcoal is dry, or remove it by lixiviation. It is sold to the manufacturers of superphosphate of lime at about five to six pounds per ton.

By means of flues a series of brick walls about eight feet in height are heated red hot. The walls are in pairs, each two of which are about eight inches apart. The space between each pair of walls is completely filled with the spent bone-black, the pile of which rests upon the ground. The upper end of each vertical layer forms a part of the heap of spent bone-black, which therefore covers the top of all the walls. When the walls have reached a red heat, and remained for a quarter of an hour at that temperature, enough bone-black is raked from the lower ends of the columns to cause each pile to sink about six inches. The heap of charcoal at the top supplies each column as it sinks. The same process is repeated, so that every portion of the bone-black gradually falls between the red-hot walls, and is raked out from below. The column of bone-black is sufficiently compact to prevent the ingress of much air, and the consequent burning of the carbon which would thence result. The red-hot charcoal as it is raked from below is thrown into metal boxes to cool; it is then sifted to remove the powder which has been formed, and is fit for use again.

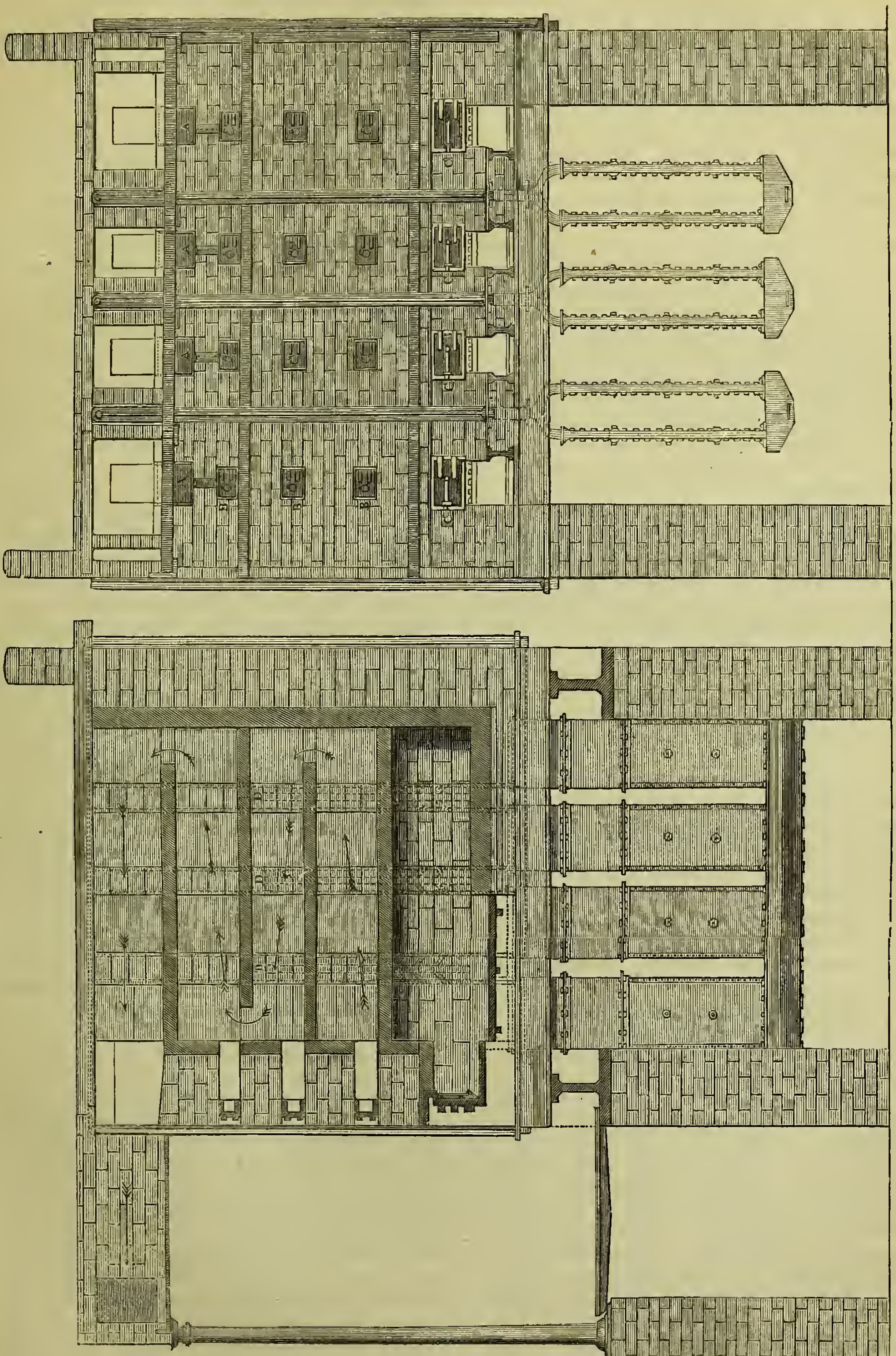
The animal charcoal effects not only the separation of the coloring matters, but also that of the excess of lime present in the sirup, and in the vivification of the spent bone-black this lime of course remains behind. It is proved, however, that the lime does in nowise impair the decolorizing power of the charcoal. It has been supposed that such lime forms phosphate of lime with the phosphoric acid contained in the coloring matters of the juice, and thus on their carbonization gives rise to a charcoal having the same decolorizing power as the original bone-black derived from animal organization. But the gain from this must be trifling.

The kiln made by Mr. CHANTRELL of Liverpool is now becoming more and more extensively used. It is of firebrick. Fig. 558 shows the kiln in elevation. Above is a hot floor, on which the charcoal is dried before it is strongly heated. The hot floor is seen also in the longitudinal section, where it is shown to be heated by the flux which comes from the furnace on its way to the chimney. The kiln represented here contains twelve chambers for the charcoal, each two feet long and three inches broad. In front there are three, and in the side view four behind each furnace door. These chambers or slits receive the charcoal at the top after drying, and, being filled up with it and heated to redness, all the organic matter in the charcoal is destroyed. When this is done, or in about forty minutes, the slide at the bottom is removed, and the charcoal falls into coolers or iron vessels somewhat narrower than the red-hot chambers. Each chamber divides into two coolers, which are exposed externally to the air, and allow the charcoal to become black, removing all fear of burning or uniting with oxygen, when it arrives at the measuring box at the bottom.

The elevation shows the furnace doors, and above them three doors to open into the flues which circulate among the chambers, as seen by the arrows in the longitudinal section. Each door has a spy-hole, which is usually kept covered. It is used to inspect the condition of the flue as to heat and cleanliness. Three perforations between the furnaces at D are holes for conveying away the gases which are generated. On the elevation the iron braces are seen at the side and between the kiln doors. This kiln is said to require much less coal than the iron pipes, saving, according to some, seventy per cent. Certainly we know the greater conducting power of heat possessed by iron. For this reason it is used for cooling, whilst bricks are used for containing the heat. Some persons expose the charcoal to the air some days before using it, believing that it is improved thereby. Many people carefully avoid using it warm. There may be a true foundation in these customs, but some careful observers have looked in vain. It is common in London for the sugar refiners to have no charcoal of their own, but to obtain it from the charcoal burners ready for use, returning it again when it is used.. For the use of a ton they pay thirty-five shillings. This may suit the London method of filtering, which is slow; but it will not suit the Lancashire method of rapid filtration. The first may last a week or more; the second only two or three days.

The burning of charcoal may become a great nuisance to a neighborhood, if not watched. The sugar sometimes left in it is decomposed, and a very

Fig. 558.



pungent vapor is sent off, whilst salts of ammonia also are found in it. To avoid these evils, it is needful to wash the charcoal with great care as soon as it has done its work. Charcoal usually contains seven or eight per cent. of carbon, and when this is removed the charcoal is of little value. It is easily removed if heated in contact with air. Its value is about thirteen pounds per ton, or perfectly dry about fourteen pounds. There is a large amount of soft charcoal, which readily goes into dust; hard charcoal is more valuable.

Charcoal is sometimes allowed to ferment, in order to free it of its acquired impurities. This fermentation generally means merely the action of a weak acid—dilute muriatic. It is useful in beet-root establishments, on account of the large amount of lime needed to throw down the substances in the juice. In the sugar, or in the juice of the sugar-cane, no such excess of extraneous matter exists, and no large excess of lime ought to be used. Such at least is the opinion of the writer, and his experience has not been small. Charcoal itself is like a cavern of mysteries, the more it is studied the more wonderful are its secrets. Science has not yet approached the difficulties as seen in practice, and partly overcome.

A mode of renewing the charcoal, by passing heated steam through it, is in actual use in France. The charcoal need not be taken from the filter, but constantly renewed *in situ.* The process may be conducted for a long time, but as far as inquiries have extended, the plan is actually more expensive than burning in kilns.

No substitute for animal charcoal has been found to approach it in value. It must be hard enough to retain its form after years of use and frequent movement. It must also be porous, and must contain fully seven per cent. of carbon.

The sirup after passing through the bone-black filter is in the state of maximum purity. The subsequent processes of the sugar-maker consist in the removal of the water. This is effected by evaporation.

4.—*Evaporation.*—The modifications of the method employed in evaporating are four:—

1. Evaporation assisted by artificial currents of air.
2. Evaporation by fire in open or closed vessels.
3. Evaporation by steam-heat in open or closed vessels.
4. Evaporation by steam-heat *in vacuo.*

The sirup after treatment with bone-black is run into the evaporating or concentrating pan; the shape of this is various according to the method of concentration to be employed. In a patent taken by G. KNELLER the heated sirup in the pan was submitted to the action of currents of cold air, which was blown through it from a perforated copper pipe immersed in the sirup. The currents of air performed the double purpose of subduing the heat of the sirup and of removing the vapor of water which was formed. The apparatus employed by M. HALLÈTE was based upon a similar principle. It consisted of two concentric copper cylinders, so closed at top and bottom with circular discs as to form a cylindrical jacket. This jacket turned upon an axis in an inclined direction, and was heated by a current of steam. The sirup was allowed to fall upon the surface of the internal cylinder at its upper end. The heated column of air and aqueous vapor in the internal cylinder determined an upward draught, which carried off the vapor; while by the rotation of the jacket the sirup was spread by centrifugal force into a uniform film upon the internal cylinder, thus exposing a great surface to the drying current. M. CHEVALIER devised an apparatus which combines the principles of those of KNELLER and HALLÈTE. The sirup in the evaporating pan is heated by the action of a coil of steam-pipe immersed in it. The pan is provided with a false perforated bottom. Air which has been heated by passing through pipes heated in a separate vessel, is blown by machinery into the pan below the false bottom. It ascends and escapes as bubbles through the perforation of the bottom, carrying with it the aqueous vapor in its passage through the sirup. This apparatus is said to be very effective and rapid in its action, but the fuel required for its working is great. A simpler and equally effective plan is that proposed by Mr. GADDESDEN, which is thus described by Dr. EVANS:—

This gentleman's apparatus consists of an iron or copper pan, having nearly the form of the half of a hollow cylinder, in which is placed a drum or wheel adapted to the shape of the vessel, and formed of a number of metal rods so arranged that the evaporating surface given to the sirup is increased as much as possible. The wheel, half its circumference being immersed in the liquid, is kept constantly revolving, so that by exposing fresh portions of the heated sirup to the action of the atmosphere at each succeeding revolution, the evaporation of the aqueous particles is rendered more rapid than it otherwise would be, while the temperature is, at the same time, in a corresponding degree reduced. The time required to take off a skip in a pan containing one ton of sugar varies from two and a half to four hours, and the temperature of the sirup ranges from 150° to 180°. From the principles upon which this method of concentration is based, it is evident that its successful working will depend upon the degree of dryness of the atmosphere, and upon the rapidity with which the air passes over the surface of the sirup. The apparatus should therefore always, when it is practicable, be placed at the windward side of the boiling-house; at all events it should be beyond the influence of the vapors which arise from the evaporating vessels.

Some manufacturers assert that the revolution of the drum is apt to occasion frothing in the sirup, however pure the latter may be—especially, as is sometimes the case, if the rods on the drum are of wood instead of iron. The advocates of GADDESDEN'S pan, on the other hand, maintain that the frothing, when it occurs, arises from albuminous and other impurities in the sirup, and that it may be entirely prevented by the addition of one or two drachms of washed butter or a few drops of fresh olive oil—an addition which, in all sugar boiling, hinders the formation of permanent bubbles, and, in GADDESDEN'S process, allows the drum to be worked at a greater velocity, and the evaporation to be thereby accelerated without inconvenience.

When the water is expelled from the sirup by the simple application of heat to the evaporating pan, and without the aid of mechanical means to increase the evaporating surface of the sirup, the heat applied must be greater than when such helps are had recourse to, in order that the sirup may be concentrated in a reasonable time. For this reason, the evaporating pans must be so constructed and filled with the sugar as not to allow the parts of the pan above the liquid to become unduly heated, and to cause thus the caramelizing and blackening of the sirup. Great care must on this account be employed in the firing of such pans. Where open pans are employed, that is, where the sirup is boiled at the ordinary atmospheric pressure, the approach to sufficient concentration for removing to the crystallizing pans may be judged of either by the physical appearance which a portion of the sirup presents when removed from the evaporating pan, or by the temperature which the sirup assumes; for a sirup consisting wholly of crystallizable cane sugar and water, boils at temperatures which are higher, according as the quantity of water it contains is less. The examination of the physical appearances of the sirup for this purpose is called proof by touch. When the sirup is approaching concentration, it presents the following appearances in succession :— 1. A copper ladle dipped into it, inverted and withdrawn in such a manner that the edge of the ladle is horizontal, is covered with a layer of sirup of uniform thickness, which drains off, not in isolated streams, but, for some distance, in a continuous sheet. 2. On taking a pinch of the sirup between the fore-finger and thumb, and depressing the latter, the sirup separates, and the drop on the finger is nearly equal in size to that on the thumb. 3. By the separation of half an inch, a thread is drawn out, which finally breaks below, the end of the thread becomes hooked, and it rises slowly towards the finger. 4. The same thing occurs at a greater distance, the end of the thread is folded back, and gives to the thread the shape of a long ribbon or stick, which rises more rapidly than before. 5. After a greater separation of the fingers, the thread breaks, being very fine at the end, which turns aside and twists up like a corkscrew. It does not fold itself upon the rest of the thread as before, and the thread does not increase in volume, except by the cohesion, which draws the particle towards the finger, which is the only adhering point. A little more concentration prevents the thread from shrinking at all.

The proof by blowing is performed by dipping a perforated copper ladle—the holes in which are about one-eighth inch in diameter—into the sirup, and then, inclining its edge at an angle of about 45°, the workman blows strongly into the cavity of the ladle, whereon, if the sirup be well concentrated, bubbles are formed of half an inch in diameter on the other side of the ladle.

The following table shows the connection between the temperature of the sirup and the amount of water it contains for one hundred parts by weight of sugar. It shows, also, the degrees of concentration at which some of the above-mentioned terms are applied. The table is from DUMAS :—

Temperature. Fahrenheit.	Composition.		Name.
	Sugar.	Water.	
213·8	100	124·66	—
215·1	100	106·81	—
215·6	100	88·96	—
217·4	100	91·11(?)	—
219·6	100	53·26	—
220·1	100	47·26	—
221	100	41·63	—
223	100	36·00	Weak hook.
226	100	28·52	Thin thread.
231	100	25·05	Common hook.
233·6	100	18 84	Strong hook.
246·2	100	—	Ordinary bubble.
248	100	—	Perfect bubble.
234·5	100	—	—
239	100	16·29	—
251	100	—	Small fracture.
263·3	100	10·92	Large fracture.
270·5	100	—	Fracture on the finger.
271·4	100	—	—

It appears from this table that when the sirup has reached 248°, although water continues to be given off, yet the temperature sinks to 234·5°, after which it again rises. If there be no error in the observation, this is probably due to the formation of a definite hydrate of sugar, which requires a higher temperature for its decomposition; but that decomposition being once determined, the water expelled takes up the caloric as latent heat in its conversion into steam, thus depressing the temperature of the sirup.

The danger of caramelizing portions of the sugar, and thus impairing not only the beauty of the product, but, by the formation of noncrystallizable sugar, diminishing the quantity obtained, has caused sugar manufacturers to seek for means by which this evil may be avoided. The vacuum pan of HOWARD answers this purpose completely. It is universally employed in Europe, and to a large extent in the Colonies.

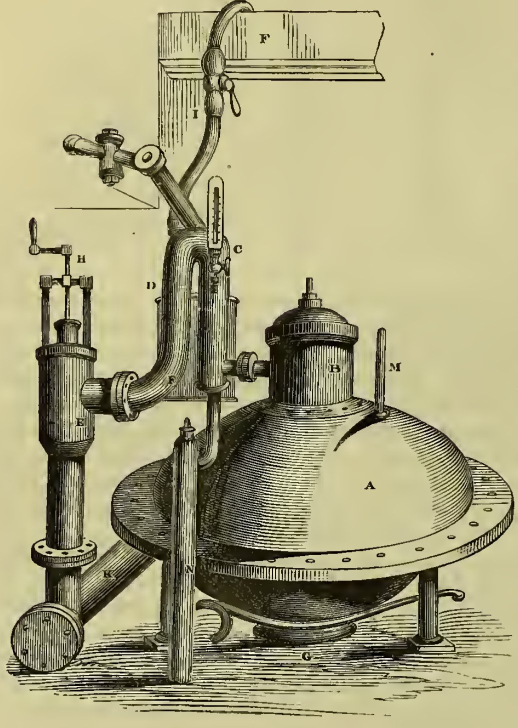
All liquids boil at lower temperatures when the pressure upon them is lessened. The pressure exerted by the atmosphere upon liquids in open vessels varies from fifteen to ten pounds per square inch. In a vacuum no such pressure exists, and, therefore, liquids boil at lower temperatures than in open vessels. HOWARD'S process for concentrating sirups consists in heating them in vessels from which the air has been wholly or partially withdrawn, that is, in more or less perfect vacua. The heat is applied to the sirup in the evaporating pan by means of a pipe containing high-pressure steam.

The following table gives the boiling point of the sugar in a vacuum pan, at different pressures of the air :—

Height of barometer in inches	Boiling point.		
	Fahrenheit.	Centigrade.	Reaumur.
0·74	115	46·11	36·89
0·86	120	48·89	39·11
1·01	125	51·67	41·35
1·17	130	54·44	43·56
1·36	135	57·22	45·78
1·57	140	60·00	48·00
1·80	145	62·78	50·22
2·05	150	65·55	52·44
2·36	155	68·33	54·67
2·72	160	71·11	56·88
3·10	165	73·89	59·11
3 52	170	76·67	61·33
4·00	175	79·44	63·56

The drawing on next page—Fig. 559—shows the various parts of HOWARD'S pan.

Fig. 559.



The principles employed in evaporating by Howard's method, namely, the use of steam as heating agent, and the employment of a vacuum, have received several modifications. These are principally those of Roth, Derosne and Degrande, and Rillieux.

The modification of Roth consists in the absence of the air-pump to produce the vacuum. The vacuum is formed by condensation alone, and this condensation is effected in a separate vessel. It has not been found possible to work so entirely free from air. This process cannot be used without some aid from a pump.

The evaporating pans of M. Derosne differ from those of Roth in the shape of the condensing vessel, which in the former's consists of a tube bent like a cracker, the folds of which lie in a vertical plane. Instead of effecting the condensation by water, Derosne employs sirup, which, being allowed to flow upon the upper fold of the tubes, trickles down from one fold to another. In condensing the steam in the inside of the tube, the sirup which flows down the outside of the tubes becomes itself heated, and parts with a portion of its water; while the heat of the tube and its vertical position determine an ascending current of air, which removes the vapor of water as it is formed.

Derosne's plan has been modified by M. Degrande by the introduction of an air-pump to complete the vacuum, and employing the vapor given off from the sirup in one pan to heat the steam-pipes in a second one. It should be mentioned that in Derosne's apparatus the sirup is allowed to flow from the pan into a closed vessel, so as not to impair the vacuum. The disadvantages of the plans of Derosne and Degrande consist in the complexity of the apparatus they require; in other respects an excellent sugar is obtained with great rapidity.

The system employed by Rillieux is the same in principle as that of Degrande. The vacuum is formed by an air-pump worked by a steam engine, and a succession of evaporating pans are employed, the sirup of each pan being heated by the vapor from the sirup of the preceding pan, and furnishing itself the vapor for heating the succeeding sirup. Each pan, however, may be connected directly with the boiler. The steam-pipes in each pan do not form, as is usual, one single layer, but they are piled upon one another like the boiler pipes of a locomotive.

5.—*Crystallization.*—Each mould stands over a separate earthenware basin, or over a leaden trough, which conducts to a cistern. When the moulds are filled with the concentrated sirup—the bung being in its place—the sirup after six or eight hours shows signs of crystallization. It should then be repeatedly stirred, so as to equalize the temperature throughout, and to distribute the crystals already formed, from which the subsequent crystallization is carried on. Several patents have been taken out for the purpose of using atmospheric pressure. The small ends of the sugar loaves may be united together, or, in other words, all may meet in a tube which runs along and connects itself with the pump. In this way they are all readily drained. The loaves are then removed to a warm room of uniform temperature. After twenty-four hours' standing the loaf is set, that is, it has attained a sufficient consistence to admit of draining. It is with concentrated saccharine liquids as with all other saturated saline solutions, namely, that such a solution, during the process of crystallization, deposits crystals which are larger according as the crystallization takes place more slowly. Hence, if the sugar be required in large grains, the sirup should be kept still; if a fine-grained sugar be required, repeated agitation must be employed during the process of solidification. When the loaves are judged to be sufficiently set the bungs are withdrawn from below, and the mother liquid, which is of course a saturated sirup at the temperature employed in crystallization, is allowed to drain off for two or three days. It is a well-known fact that when a solid body separates in the crystalline form from a solution which contains foreign soluble impurities, the crystals are more free from such impurities than the liquid from which they separate. Hence, in the above-formed loaves, the crystals of the loaf are purer than the sirup which runs from them; they would indeed be of the maximum degree of purity were it not for the sirup with which they are still moistened. The next process consists in the removal of this adhering sirup. Formerly this was effected by the method of *claying.*

This consisted in scooping a shallow hollow in the thick and upper end of the loaf by means of an instrument called a bottoming trowel, and filling the hollow with a paste made of fine white clay and water. The water gradually leaves the clay and percolates downwards through the loaf, carrying with it the colored sirup, and dissolving also from the first strata a portion of the crystallized sugar. In its descent, as it becomes saturated with sugar, it acts simply by displacement, forcing out the colored mother-liquor or molasses from below. The fact that in this process a portion of the solid and whiter sugar is dissolved renders this method a wasteful one; it is now but little employed. In the process of *liquoring* the principle of displacement is alone employed. In this method the top of the loaf is levelled, and upon it is poured a saturated or strong solution of colorless sirup; as this sinks down it displaces the colored molasses. When the sirup commences to flow nearly colorless from the hole below, the loaf is allowed to drain, then inverted to distribute the sirup uniformly, and transferred to the drying oven. M. PAYEN mentions the following points in connection with the process of liquoring:—

1. The liquor must be sufficiently charged with crystallizable sugar to dissolve little or nothing in filtering.

2. The density of the liquor must be nearly the same or very little less than that of the displaced sirup; for if too dense it would flow badly: if too dilute it would escape without removing the sirup or molasses adhering to the crystals. To attain this condition the sugars used for preparing the liquor must be more impure in proportion as those to be liquored are so; for saturated sirups are more dense and viscid when they contain non-crystallizable sugar.

3. The crystallization in the moulds must be regular and not too compact; and for this end it must commence and terminate in the same vessel.

4. The temperature of the room in which the liquoring is performed should not vary much, and should be at least 70°. The operation of liquoring is performed as follows:—The crystallization is complete in twenty hours. The superficial crystalline crust is then removed from the base of each loaf with a trowel, and the surface is levelled. These surface scrapings—or rather those of a previous day's work —are added to sirup until the density becomes 67° Twaddell at 60°.

About five pounds of this liquor is poured at one time into each drained mould, containing about sixty pounds of crystallized sugar, which corresponds to ninety-three or one hundred pounds of concentrated sirup, put into the mould. This operation is repeated three times at intervals of twelve hours, and the sugar is then allowed to drain for three or four days. At the end of this time it may be put into casks, and it will be much drier and less alterable than ordinary brown sugar.

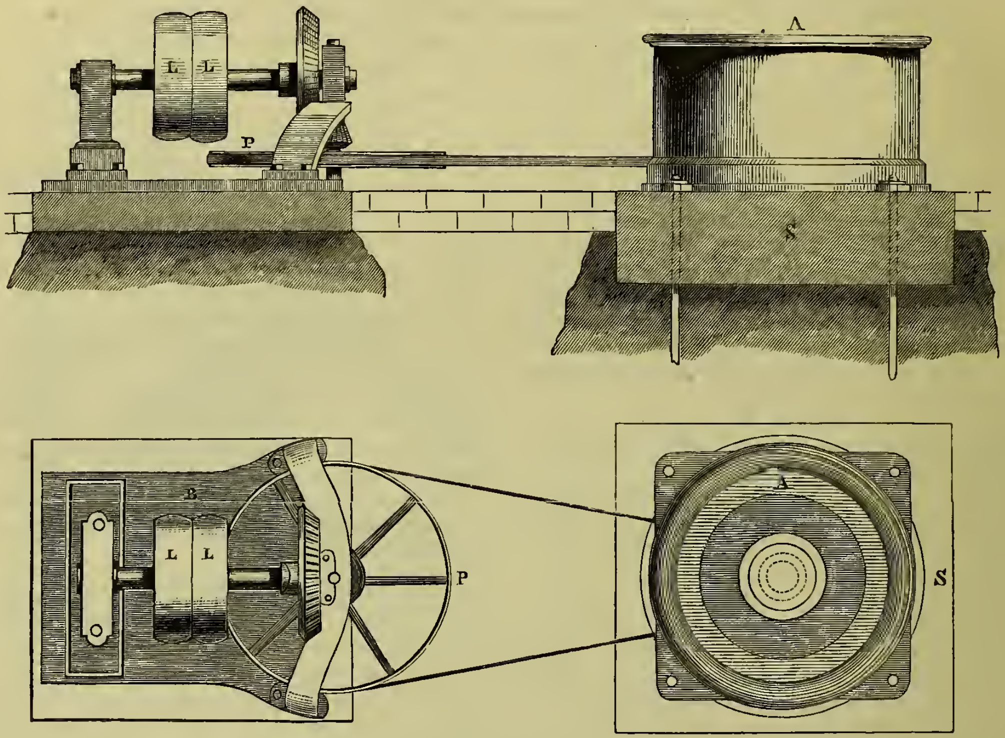
Instead of allowing the mother-sirup to drain out by the force of gravity alone, recourse is sometimes had to the pressure of the atmosphere. This is applied in the following manner:—The moulds are rectangular boxes, about six feet long, four feet broad, and two deep; they are called *tigers*. They are provided with false bottoms formed of wire gauze or perforated plate. When the sugar is set the space between the real and false bottom is exhausted, and the pressure of the atmosphere forces the sirup from among the crystals of sugar into the hollow space. The mass of sugar which has been thus rapidly drained is either dried at once or previously stamped, to give it compactness, into brass moulds. It has been supposed in the above account, that loaf sugar is to be made; if so the filtered part is reboiled and again crystallized, by which means a sugar of an inferior color is obtained. The filtered portion of this second crystallization is also boiled down and crystallized, producing a third quality of sugar. The liquor from this last is the *treacle* of this country, or if clarified, it is the *golden sirup*. By this means the sugar is divided into *fine*, *seconds*, *bastards*, and *treacle*. Lump sugar is not necessarily white, nor is moist sugar necessarily brown. In making any of these sugars, the crystals are not allowed to stand and harden, unless lump sugar be wanted. If lump sugar be not wanted, the rotary machine is used instead of drainage to separate the sirup. At the same time, in the rough management of the colonies, one boiling down is common, the molasses coming from it being used for rum, or perhaps entirely thrown away, as frequently happens in Cuba, far from the coast.

The sugar with the adhering sirup is then introduced into the centrifugal drying machine, which is shown in Fig. 560 succeeding page.

The crude sugar is placed in the cavity as far as the rim extends. On bringing the drum into gear the box is turned round with a velocity of about 1000 to 1700 revolutions per minute. It follows that the contents of the box are forcibly pressed outwards. The crystalline grains are retained by the copper casing, while the molasses is forced through its interstices and thrown off into the outer reservoir. A rotation of a few minutes is sufficient for the drying of a charge of sugar. The machine is then stopped and the sugar is scraped out with a trowel. The sugar so obtained has seldom the brilliant whiteness of loaf sugar, nor does it possess the same compact form; but the immense saving of time effected by the use of the centrifugal drying machine is bringing it more and more into use.

The very large crystals, remarkably distinct and difficult to dissolve, which have of late been manufactured, are made by boiling to partial crystallization in the vacuum pan; drawing off half and adding fresh sirup, this may be repeated to any size of crystals. In countries where the cane is grown, it is usual, to employ the molasses or treacle for the manufacture of rum, or to export it to Europe to the sugar refiners. The coarser kinds of sugar, moreover, which are made from unclarified or imperfectly clarified juice, and which are known as moist or brown sugar, are also bought by the European refiners, who separate the white sugar from the molasses which they contain. A great loss is experienced by the transportation of sugars from the Americas to Europe. This is in part occasioned by the gradual and more complete separation of the molasses which drains off and escapes into the hold of the vessel, such draining being greatly facilitated by the motions of the vessel; but partly and perhaps chiefly by the escape of the sugar which such motions produce. The whole bulk of a sugar vessel becomes impregnated with sugar, and metallic bodies in the ship which are far removed from the sugar in cargo, become speedily tarnished and corroded, owing to the deposition upon them of particles of sugar, and the subsequent fermentation and acidification of such sugar.

Fig. 560.



Sugar Refining.—The great difference in price between coarse and white sugar, the cheapness of fuel and the facilities of making and repairing machinery in Europe, have given birth to its sugar refineries. In the sketch of the preparation of sugar from the cane —Fig. 560—it is supposed that the whole process is carried through at once. But where the crude products from the colonies are bought by the European refiner for purification, his process differs only from the above-described one, inasmuch as he has at starting solid brown sugar or molasses to deal with, instead of the juice of the cane at its natural degree of dilution. The refiner, therefore, at starting has to dissolve his sugar or dilute his molasses to the necessary degree in order to submit it to filtration. The processes which the refiner has to perform depend, of course, entirely upon the nature of the raw sugar with which he has to deal. In most cases the material which comes into his hands has undergone the process of defecation, but not that of filtration, or the filtration where performed has been very incomplete. To dissolve the raw sugar warm dilute sirup is employed. The sugar is agitated with the sirup by means of a flanged wheel worked by machinery, and the product is then pumped up to the top of the refinery. It then undergoes the various processes of filtration through cotton bags and charcoal and evaporation, which have been already described. In refineries the evaporation is always effected in vacuum pans, and the drying is generally performed by the centrifugal machine.

Abridged description of the Process of Refining.—As conducted in sugar works here, the process of refining consists simply of the following operations:—The bags are cut up and thrown aside to have the sugar washed out of them. They may be thrown away, or they may be sold for paper, according to their value. The sugar is thrown into a pan which will contain from two to three tons of it in solution. Sometimes it is broken up by a spade, sometimes by machinery cutting it with revolving knives. It is heated more or less; some bring it to boiling. Frequently, if not generally, it is treated with a little lime water; this is called defecation, or blowing up. It is then sent through the bag filters, from which it passes into great iron tanks, where it waits till a charcoal filter is ready. It then passes on to the charcoal filter, and from thence to the vacuum pan to be boiled down. It is then set to crystallize. When this is done, it is freed from its liquid sirup or molasses by the centrifugal machine. Instead of being put into this machine, it may be poured into sugar loaf moulds and washed with sirup. This is sometimes called claying, and is made to sound mysterious. Both processes are one in principle, as sugars when put into the centrifugal machine are in reality washed with sirup.

	Beaume.	Fahr.
Defecation takes place at......	27	and about 180°
Syrup runs from the charcoal at	27	“ 80°
Syrup from first crystals,......	40	“ 100°
Reduced to 25° Beaumé for boiling to obtain second crystals—		
Drainage from second grain....	40	“ 100°
Drainage from third grain	34	“ 80°
Drainage or treacle at the last	41-43	

Sugar is soluble in one-fifth of its weight of boiling water, and one half its weight of cold water. Six pounds of sirup, containing five of sugar and one of water, deposit on cooling three pounds of sugar, leaving three pounds of sirup containing two of sugar. Sirup containing one of water to five of sugar boils at 238° Fahr., but it is evaporated till the boiling point is as high as 240° or 242°. If evaporation takes place in the open air, this temperature is actually attained; if Howard's pan is used, no matter what variety of shape be chosen for the pan, the vacuum brings down the boiling point as low as to 145°, but on an average we may say that the sugar is boiled down in the vacuum pan at 160° Fahr. In the open air the appearance indicates the condition of the sirups. In this country the vacuum being of necessity used, a specimen of the sugar is removed by the proof stick. This is simply a brass rod, which is driven from the upper part of the side of the vacuum pan down an aperture made of the same size as the rod. When it reaches the bottom, the rod is twisted half round by the cross handle, and opens a communication with the end of the rod and the sirup. In the end of the rod is a groove into which the sugar enters; the rod is half turned again and drawn out, and the entrance is closed as at first. A portion of sugar is taken between the finger and thumb, and the indications are obtained which have been already described. When the sugar is ready, the vacuum pan is opened, and the sugar falls out into a large copper. There are various ways of disposing of it at this period; but in every case it is put into a series of small vessels. If loaf sugar is to be made, it is here heated up to nearly boiling. In some places it is put into pans of earthenware not unlike, or it may be exactly like the sugar loaves, even although there is no intention of making loaf sugar. Sometimes these vessels are made of zinc, and painted; iron has been tried. Sometimes the vessels are very large, containing from one to ten hundredweight of sugar. These vessels are allowed to cool slowly. For fine sugar 90° Fahr. is used, for common 115° Fahr., during which time the crystallization takes place. Every vessel must, of course, have an aperture at the bottom, which is opened for drainage as soon as crystallization has commenced. Each vessel has a drain under it communicating with a general receiver; when the drainage ceases the sugar—in houses on the newest system—is taken to the centrifugal machine, unless, of course, loaf sugar be made. The time of standing is from two to six days. The sugar when crystallized is surrounded with colored sirup, not so pure as the sirup which comes from the charcoal; time and workmanship have produced a dark hue again. It has become exceedingly hard, the crystals being strongly held together, some very dark-colored sirup still remaining. It is removed from the moulds or forms by a pickaxe and spade, or more frequently by a cutter, which is of the same curve as the inside of the crystallizing vessel, and which, being driven by considerable force, scoops out the sugar readily. In order to remove the liquid about three minutes are required. It is often the case that the sirup has hardened too much, and it is then needful to soften it with a jet of steam, which enters the side of the *hydro*, as the hydro-extractor is technically called. The liquid, with all the impurities, flows off by an underground pipe, and is used again. The first crystallization produces fine sugar; the next, seconds; and the third, bastards. The uncrystallizable treacle is the fourth product. When loaf sugar is to be made, the moulds are of the well-known size, containing about thirty pounds.

Special description of the more complex machines, with some additional details.—In order not to load the account of the processes used in sugar refining with the description of too many machines and minute details, the special parts of the apparatus will be more minutely described in this part of the article, and additional particulars given for those who desire to enter more fully into the subject.

Sugar Mill.—Fig. 561 represents the arrangement of mill and boiling-house as used in the colonies. The size of a sugar plantation in the West Indies varies from one hundred and fifty to two thousand acres, producing from one hundred to five thousand hogsheads of sugar per annum. The boiling-house should be situated in a central position on the plantation, to avoid loss of time in carriage of the canes from the fields to the mill. The mill A—Fig. 561 and drawn to a larger scale in Fig. 554—consists of three heavy cast-iron rollers, about two feet four inches diameter and four feet long, fixed in strong cast-iron frames. The canes are fed from the feeding table, B—Fig. 554—and are squeezed twice between the top roller, C, and each of the two lower rollers, D and E. The megass, or solid part of the cane, after being squeezed passes from the mill by the shoot, F. A trash-turner, G, is placed between the two lower rollers, and under the top one, to guide the canes between the upper and second lower roller. The spaces between the upper and lower rollers are adjusted by the screws, H H; the space between the top and first lower roller should be a quarter of an inch, the second lower roller being set close to the top one. The juice drops into a trough below, from which it runs to the clarifiers, directly if possible; but if the mill cannot be placed sufficiently high to command the clarifiers, a pump is used, worked from the top roller spindle and fixed in a cistern under the trough. The speed found most advantageous for expressing the juice from the canes is at the rate of twenty feet per minute at the periphery of the rollers. The two lower rollers are driven from the upper one by spur pinions, I I I, keyed on the ends of the spindles. The mills are driven by steam—as shown in the drawing—but sometimes water or wind power is used according to the physical character of the country in which it is used. Cattle are also employed to work them in some places, especially on small estates where fuel is difficult to be obtained. In cattle mills the rollers are usually vertical instead of horizontal, being simply driven by yoke arms fixed to the spindle of the

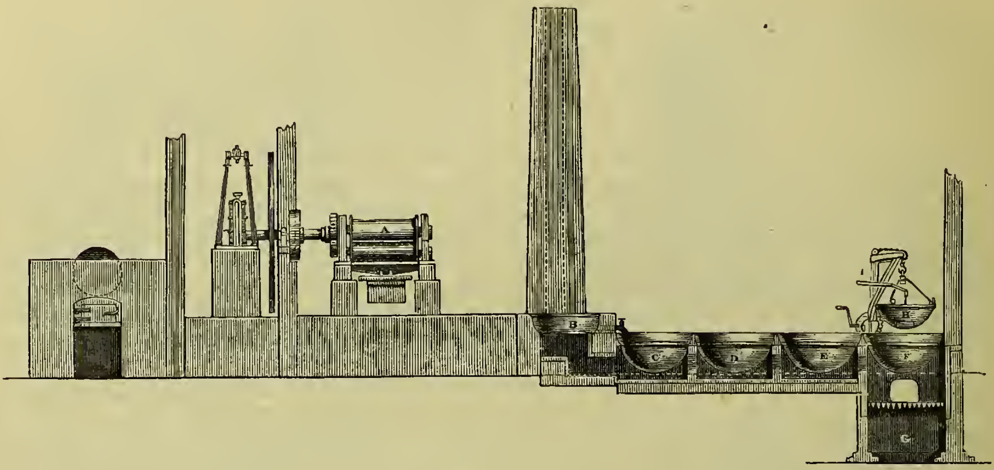


Fig. 561

centre roller; the cattle working from the ends of the arms. The rollers, three in number, are fixed in a line with each other, the two outside ones being driven from the centre roller by spur pinions keyed on the tops of the spindles. The weight of the rollers is carried on hardened steel plates fixed in the framework of the mill; a steel toe being fitted to the bottom of the spindle to bear on the steel plates. The canes are fed between the first and centre rollers, the megass coming out on the same side between the centre and third roller, a piece of plate-iron bent to a sweep corresponding to the diameter of the centre roller, guiding the canes round to be squeezed the second time between the centre and third rollers. The juice falls into a trough placed under the three rollers. A cane carrier is often used to supply the canes to the horizontal mill. It consists of two endless pitch chains working over barrels, the upper one being driven from the spindle of the top roller by spur-wheels or another endless pitch chain. On the outer side of the chains are attached boards sliding over a wood framing, with a ledge on each side to keep the canes on the carrier. The top of the carrier is level with the top of the feeding table and extends some thirty feet from the mill. The canes are delivered on the carrier instead of on the feeding table of the mill, which facilitates the work, besides causing the mill to be more regularly supplied with canes than when they are delivered on the feeding table of the mill.

Clarifiers.—The juice, as it is expressed from the canes, runs into the clarifiers, one of which is shown at B—Fig. 561. Two are generally used, one filling while the juice in the other is clarifying. They are generally cylindrical copper-pans with crown or arched bottoms to resist the action of the fire. They are fitted with a large cock at the bottom for running the juice into the first copper. They are set in brickwork at the end of the battery, the flame passing under them previous to going into the chimney, a damper being provided to each to direct the flame under the one that is full. Milk of lime is added sufficient to neutralize the acid in the juice.

The battery is a range of pans, C D E F, with the furnace, G, at one end. The fire passes under the range, and under either of the clarifiers to the chimney. The pans are hemispherical in shape, diminishing in size from the first copper, C, under the clarifiers, to the striking teach, F, in which the evaporation is completed. As the juice becomes concentrated in the pans nearer the furnace, they are filled up from those behind them, until the striking teach is sufficiently full, and the sugar in it concentrated to the granulating point. It is then ladled into shallow wooden vessels, where it is allowed to cool, and from thence it is conveyed into the hogsheads in the curing-house. An improvement in the old system of ladling from the striking teach to the coolers is now much used. It consists of a copper pan, H, fitting the inside of the striking teach as accurately as possible. At the bottom of this pan or dipper is a large valve opening towards the inside of the dipper, the valve being worked by a lever, I, over the side, and a chain from the ground. The dipper is attached to a crane, J, which commands the striking teach and a gutter to the coolers. The advantage of the dipper is that the striking teach can be emptied and refilled in much less time than by the ladle, and consequently there is not so much risk of burning the copper and the sugar. A gutter is made in the brickwork at the side of the battery into which the impurities that rise to the surface of the liquor are skimmed. The skimmings—from which are distilled the best rum—are convêyed from the gutter to a tank previous to fermentation. The floor of the curing-house, in which the molasses is drained from the sugar, is composed of a series of gutters which incline to the centre of the building and deliver their contents to a main gutter which communicates with a tank for the molasses. The hogsheads are placed on end over the gutters, small holes being bored in their ends for the passage of the molasses. The sugar, after remaining in the curing-house about fourteen days, is ready for shipment, and is known in the market as raw or muscovado sugar.

The megass, after passing through the rollers of the mill, is dried and used as fuel for the battery; being better suited for that purpose than any other convenient fuel, as far as heat goes, a very quick fire being required. A saving of fuel is effected by placing the boiler of the cane-mill engine at the end of the battery, so that the products of combustion may pass from the battery through the boiler flues, previous to going into the chimney. A furnace is fitted to the boiler for use before the battery is at work in the morning, and which can be shut off when not required, the waste heat from the battery being almost sufficient to work the boiler for the cane-mill engine.

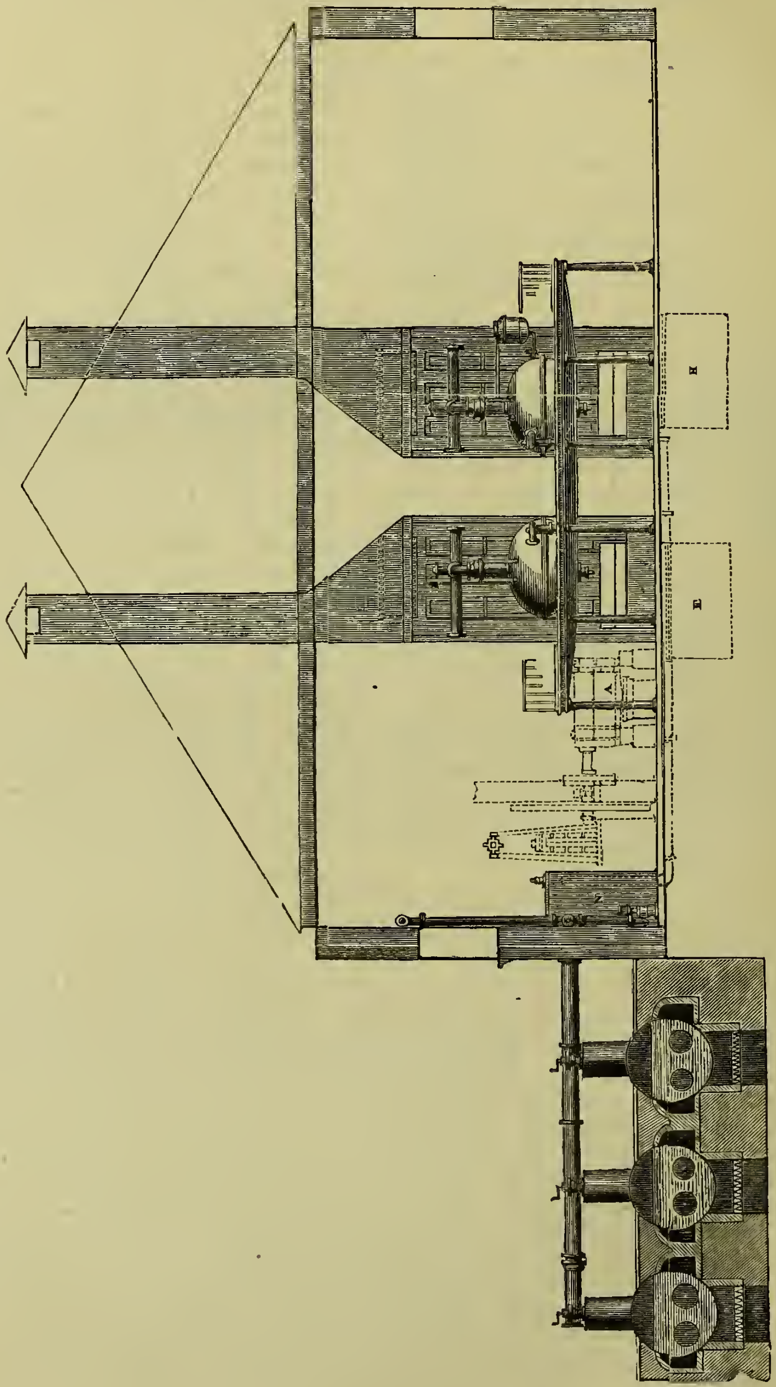
In the striking teach of the ordinary battery there is a liability of the upper part of the teach becoming overheated, and so making the sugar of a darker color when it splashes up against it, depreciating its value. A pan made so that the heating surface is entirely covered with liquor is used in some places, called a *baseule* or tiltpan. It is a shallow, cylindrical, copper pan, about five feet diameter and two feet deep. It is furnished with a lip to run off the sugar, and works on a hinge under the lip. The pan is set over a fire, and when the sugar is boiled to the granulating point, it is tilted up by a lever and chain fixed to it. The sugar being turned out at once into the cooler, there is not the same risk of burning as in the ordinary fixed pans.

Rectangular copper pans with crowned bottoms have also been substituted for the hemispherical pans with cocks or valves, to empty them from the bottom. They are ranged side by side over the furnace, so that the flame runs under them from end to end; and there being no side flues, the metal of the pans does not become heated, and consequently the quality of the sugar is not injured.

Figs. 562, 563, 564 show a boiling house fitted up with the latest improvements in the machinery connected with the manufacture, for facilitating the process and improving the color and quality of the grain. It is worked wholly by steam heat, as being more economical in the working, and admitting of more perfect regulation of temperature. The juice from the mill, A—as described before—is forced up to the top of the building to the clarifiers by a *monte-jus* or juice elevator, B, consisting of a wrought-iron vessel into which the juice flows from the mill by a pipe and cock. Another pipe is fixed to the top of the monte-jus and rises to the required height, dipping down to near the bottom of the monte-jus; the steam being admitted at the top forces the juice up the pipe. This is more convenient than a pump, is cleaner, and not so liable to acidify the juice. The clarifiers, C C C, used here are hemispherical copper pans, hammered out of one piece of copper fixed by a flange laid off to an outer cast-iron pan, allowing a space between the pans for steam. A copper light course is fixed to the top, the heating surface not being required up to the top of the pan. A valve is attached at the side to regulate the supply of steam, and a two-way cock at the bottom; the smaller branch being for the clarified juice, and the larger for the scum. The juice in the clarifier is raised to a temperature of 176°. Milk of lime is added sufficient to neutralize the acid in the juice. The heat is then continued till a scum, consisting of impurities present in the juice, has risen to the surface and appears about to crack. The time occupied in this should be about ten to twelve minutes from the commencement of the operation. The steam is then shut off and the liquor allowed to subside for fifteen or twenty minutes, when the scum will be found to remain at the top; some heavy matter, such as dirt, *et cetera*, will have fallen to the bottom, and between them will be the clarified cane juice, clear, and of a pale straw color. The clear liquor is separated from the impurities in the following manner:—At the bottom of each clarifier is a plug, ground into the top of the cock, with a rod and handle above the top of the clarifier. At the side of the plug are holes about three or four inches above the bottom of the clarifier, adjustable by a copper clip, below which all the heavy matter will have accumulated. The clarification then being complete, the cock is first turned on to the smaller aperture until the scum accumulated at the top begins to appear. The cock is then turned to the large way and the plug taken out. The heavy matter at the bottom and the scum formed during the process are conveyed to a cistern, from whence it is placed in bags, and any juice remaining in it is squeezed out, leaving only a small portion of solid matter behind. The clarified juice or liquor, after coming from the clarifiers, is passed through mechanical filters. The kind commonly used are rectangular cases of cast or wrought iron with an internal flanch at the top to support a copper box, about twenty inches deep, to receive the liquor to be filtered. At the bottom of the box a number of holes are drilled and screwed to receive the bells or connections, to which filter bags are attached. These bags are made of twilled cotton cloth, about six feet in circumference and six long, wove without a seam. They are inclosed in a strong open webbing, about eighteen inches in circumference, thus giving a large surface of filtering medium in a small space. The filters are shown at D D D. The liquor is drawn off at the bottom into a receiving cistern, E, to supply the evaporating pan. Steam cocks are attached to the side of the cases for cleansing them after use; and doors are fixed to them for changing the bags. The evaporation is here effected in vacuo, as being most advantageous, the liquor boiling at so low a temperature as not at all to discolor the liquor or alter the saccharine matter in it. The first cost, however, of the apparatus is increased, and alone prevents its universal adoption.

The vacuum pan, F, used for the evaporation of the liquor, consists of a copper pan fitted in a cast-iron steam case, allowing a space between for the steam, and on the top is a copper dome; the copper and iron pans and dome being accurately fitted and bolted together, so as to be perfectly steam and air tight. In order still further to increase the heating surface, a large brazed copper worm is fixed inside the pan. A manhole, with a ground brass cover, is attached to the top of the dome, from the side of which a pipe leads to the receiver or safety vessel, furnished with a glass

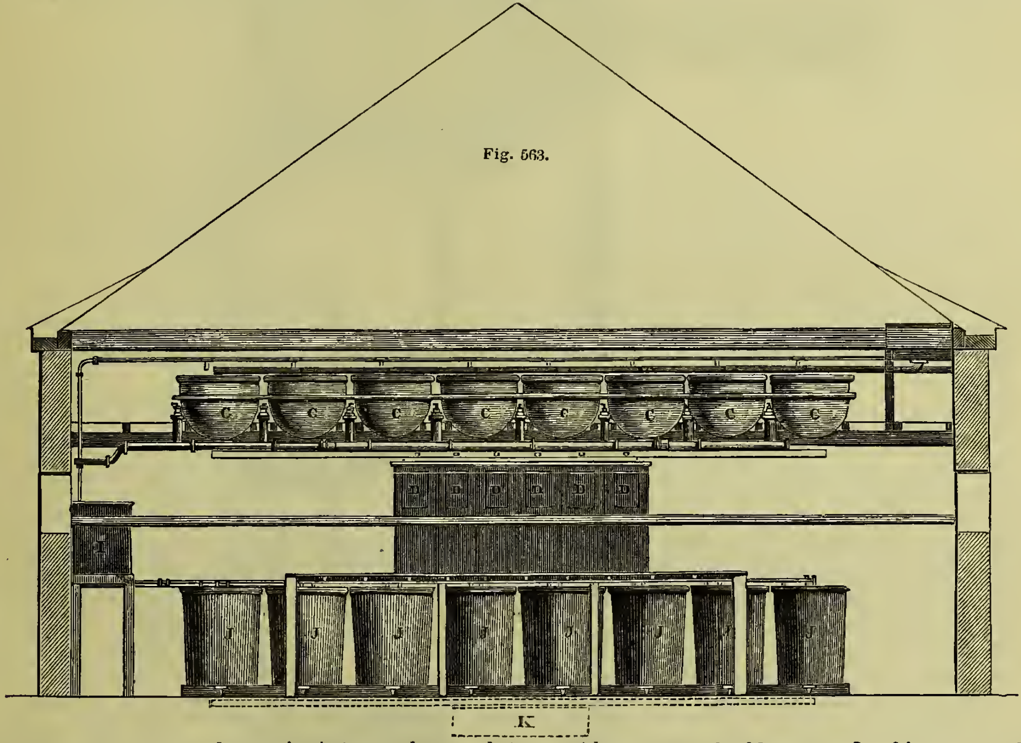
Fig 562.



guage and draw-off cock, the use of which is that the attendant may see if the pan primes or boils over ; if it does, the sugar must fall into the receiver, and be indicated by the guage. A pipe from the top of the receiver, with a valve to shut off the communication, connects the pan with the condensers. The pan is fitted with a cock at the bottom for running off the liquor when sufficiently concentrated, namely, at about 36° Twaddell. On the dome of the pan are fixed a barometer; a thermometer, with bulb dipping down into the liquor; light and sight glasses for looking into the pan ; an apparatus for testing the concentration of the liquor without destroying the vacuum in the pan ; air-cock for letting in the air when the liquor is required to be drawn off; and a steaming valve for cleaning the pan after work. Surface condensation is employed to maintain a vacuum in these pans, in situations where there is not sufficient water to admit of condensation by injection being used.

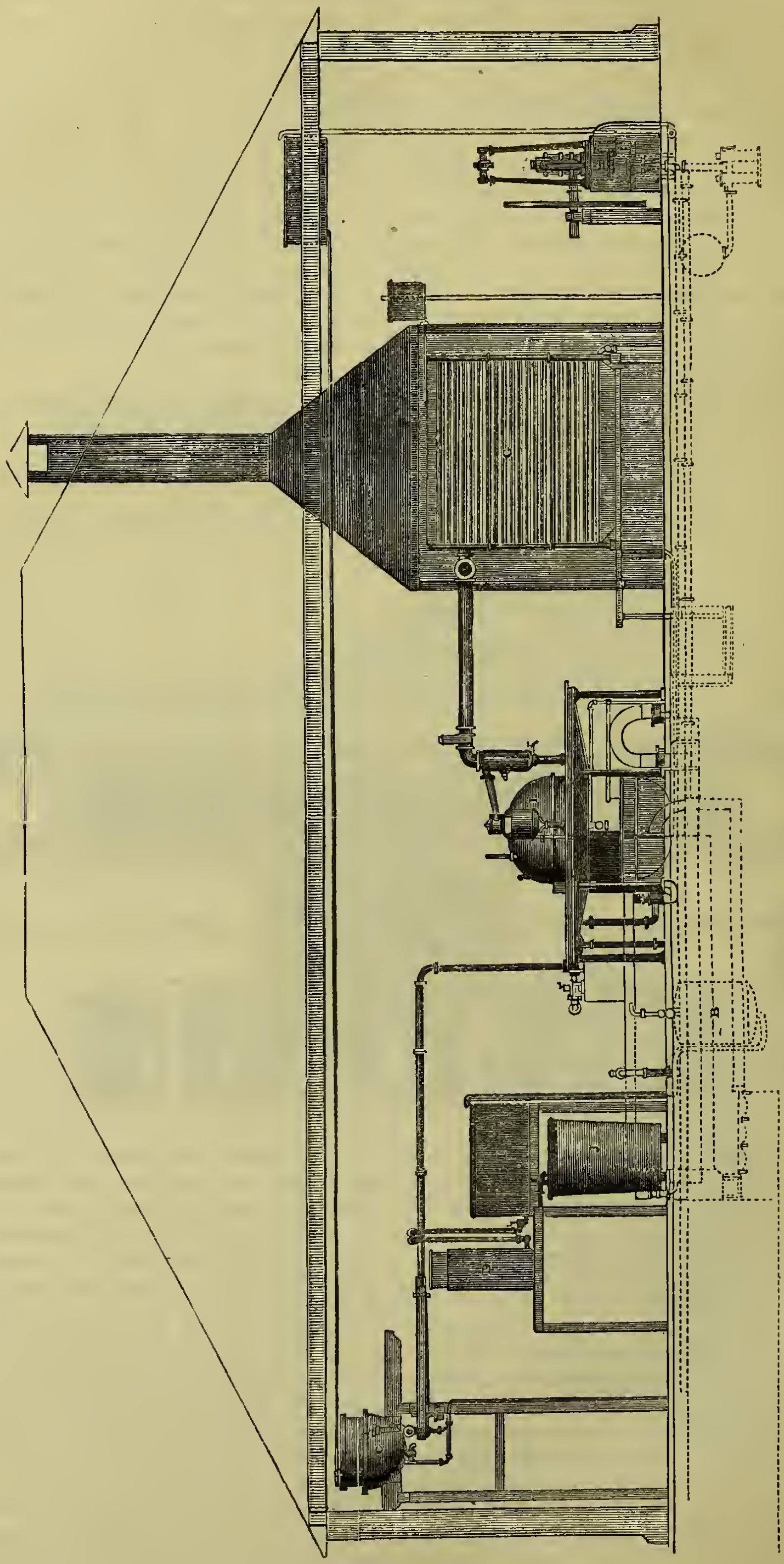
The surface condensers are here shown, G G G. This process of condensation was introduced and patented by Messrs. PONTIFEX and WOOD of London, who have recently patented a simple and efficient method of connecting the pipes—admirably adapted for the colonies, and all places where skilled labor is difficult to be obtained. The condensers consist of one or more series of copper pipes, fixed to boxes at each end, with partitions to direct the current of the vapor. Above each series of pipes is fixed a trough always kept full of water, and so constructed that the water trickles in a gentle shower, uniformly spread over the pipes, so as to keep them well covered with a thin film of water; the lowest pipe is connected with a small pump, worked by the engine, which draws the condensed vapor from the pan, and any air that may have collected there. The improvement referred to consists in doing away with solder joints at the junction of the pipes with the case, the solder being liable to crack from the unequal expansion of the pipes, owing to the lower pipes being cooler than the upper ones, and the substitution of an elastic joint, which allows for the irregularity of the expansions, without injuring the vacuum; they are also easily replaced, not requiring any mechanical skill, and take up less space for shipment; these pipes and cases being packed separately. The superior economy of water in these condensers, is owing to the condensing water being evaporated and carrying away not merely sensible but latent heat. The ordinary method of condensation is similar to that employed in the condensers of steam engines, when the steam is led into a vessel, where it is brought into contact with a stream of cold water. In this case, as the condensing water must not be allowed to become vaporized, all the heat it absorbs must be in the form of sensible heat, and it is said practically to require about thirty times the quantity of condensing water; but in these surface condensers the vapor which passes off from the surface of the pipes, not only carries off the sensible heat, but it also renders latent a great amount of heat in its conversion into vapor, the quantity of water passing off from the surface being equal or nearly so to the quantity condensed inside the pipes. The water which falls into the trough under the condenser is used over again, the heat of it not materially affecting the action of the condensers.

Fig. 563.



When sufficiently concentrated, the sugar-liquor is let down into a receiving cistern, H, placed below the pan, from whence it is forced up by the monte-jus to

Fig. 564.



a cistern, I, above the level of the top of the charcoal filters. The charcoal filters, J J J J, are large, slightly conical vessels, generally of wrought-iron, with a perforated false bottom about an inch and a half from the bottom. A blanket is spread over the false bottom to prevent the charcoal from being carried through with the liquor; some, however, always accompanies the liquor at first, which runs into a separate receiver to be filtered over again. In filling these vessels, the first few inches of charcoal should be pressed compactly down, after which it is packed lightly but evenly, nearly to the top, where space is left to receive the liquor. The object to be attained in these filters, is to remove all the vegetal coloring matter from the liquor, and any excess of lime that may have been added during the clarification, as well as some of the mineral salts, such as sulphate of lime, originally existing in the cane juice. The liquor from the charcoal filters runs into a cistern, K, preparatory to being drawn into the granulating pan.

The granulating is also performed in vacuo, and the pan, L, is similar in its construction to the one before described for evaporation, and a similar surface condenser is applied when there is a deficiency of water. To the granulating vacuum pan a measure is usually attached, so that the attendant may know exactly how much liquor he lets into the pan. There is also a proof stick or instrument for taking a sample of the sugar out of the pan during the concentration, without destroying the vacuum. A slide is fitted to the bottom, instead of a cock, for letting out the sugar when the granulation is completed. The pan is also fitted with light and sight glasses, barometer, thermometer, *et cetera.*

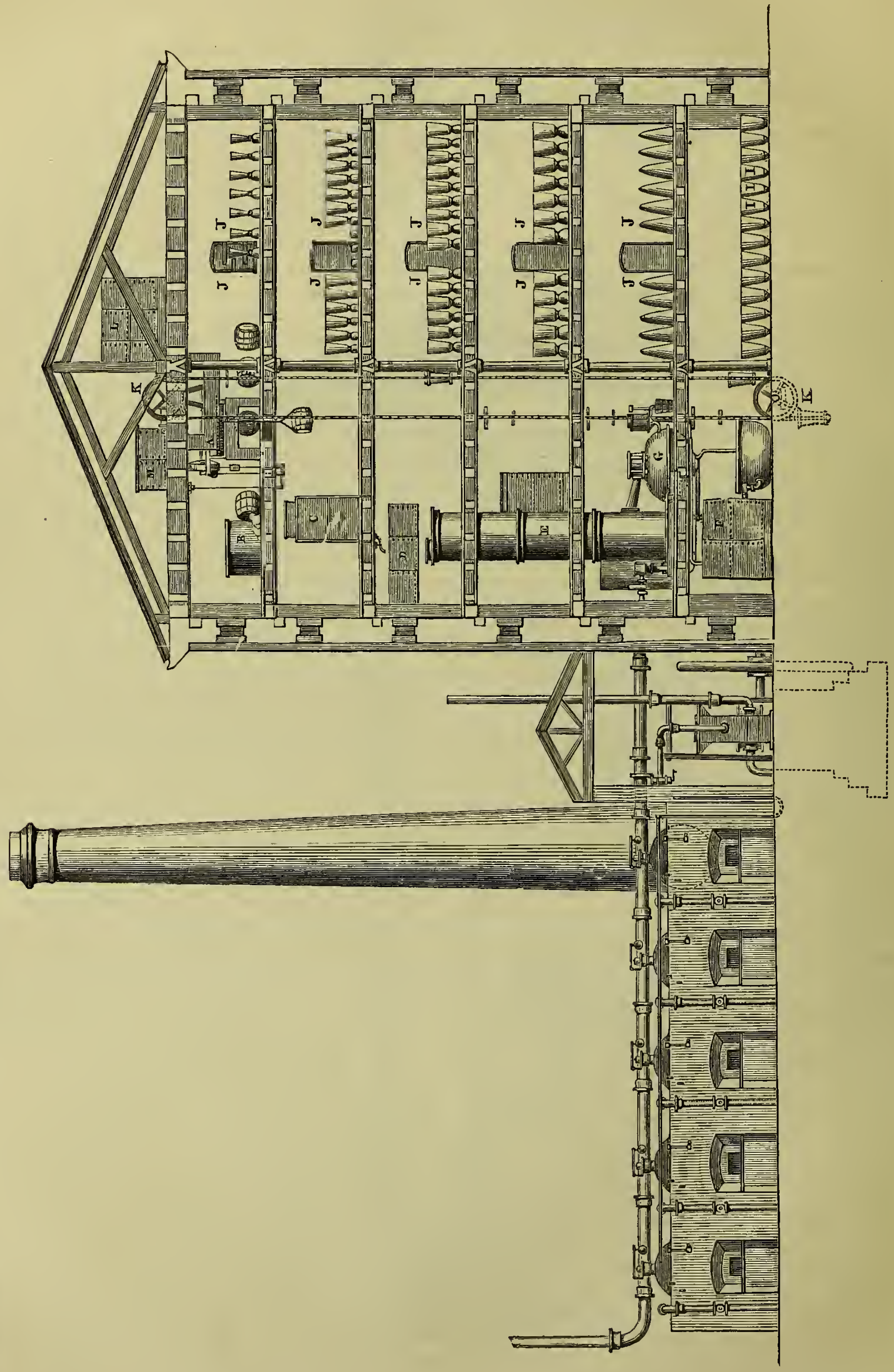
The sugar, on being let out of the pan, drops into a heater, M, a hemispherical pan of a similar description to the clarifiers described before, in order to raise the temperature of the sugar above what it was in the pan, to harden the grain previous to being conveyed to the curing-house. The water arising from the condensation of the steam in the various vessels, passes from the bottom through a condense water box attached to each vessel, in the interior of which box a float and valve are so arranged that the water passes through without letting the steam escape. The outlet pipes from the condense water boxes are carried to a cistern, into which the suction pipe of the feed pump to the steam boilers dips, to be used over again to supply them, a very small quantity of cold water requiring to be added to make up for loss by waste. In some parts of the manufacture, high pressure steam being required, such as for clarification, for the steam engine, and the montejus, it is found better to keep the steam up in the boilers to a uniform pressure, lowering the pressure to the vacuum pans and heaters when the temperature of high pressure steam would injure the quality of the sugar. N represents an expansion vessel for effecting this purpose, and is fitted with one of Messrs. PONTIFEX and WOOD'S patent improved valves, by which the steam in the expansion vessel is sustained uniformly at any required pressure. However high or fluctuating the pressure may be in the boilers, the excess of pressure shutting the supply valve to the expansion vessel, safety and whistle valves are attached to the top, and a guage on the side to indicate the pressure of steam.

The evaporation of the juice, up to 48° Twaddell, may be carried on in the ordinary battery of hemispherical pans or the improved rectangular ones, as previously described, without being seriously detrimental to the liquor, although the plan last described of evaporating, as well as granulating in vacuo, is most approved. A better method of evaporating than by direct fire heat is by using steam evaporators—the best form of which having the largest heating surface, combined with facility for cleaning, is a rectangular vessel, generally of wrought-iron, at the bottom of which is placed a range of copper pipes as close to each other as convenient. The pipes are connected together by copper bends brazed to the pipes. The entrance of the steam and exit of the condensed water are at the same end of the evaporator, and pass through stuffing boxes, to admit of the pipes being turned up, so as to be able readily to approach all parts of the evaporator to clean them—a point of great importance in the manufacture.

Machinery and apparatus, such as those described in the preceding, and fitted with all the modern improvements are, it is true, costly in erection, but they very soon pay for themselves in the superior quality of the article produced, and the greater return from the same quantity of canes. By employing the strong mills and powerful engines as now manufactured, the canes yield a much larger per centage of juice than previously; and the megass leaving the mill being much dryer is in a better condition to be used as fuel. By applying steam heat, and boiling in vacuo at low temperatures, the color is improved, and less of the sugar is converted into molasses, so that estates which were worked at a loss before may, by the introduction of improved machinery and utensils, be made to yield a profitable return. In colonies where field labor is difficult to be procured, it is especially important to the planter to obtain the most approved machinery, so as to cause as little waste as possible of the raw material.

The machinery of a sugar refinery as worked in Europe is shown in Fig. 565, which represents the elevation of a refinery of the most modern construction, for the conversion of the raw sugar, as imported, to the white loaf sugar of the consumer. The raw sugar, in hogsheads, boxes, or bags, is lifted from the waggon to the upper story of the house by a crane worked by a steam hoist machine, A. The first operation is to melt the sugar, which is usually done in cylindrical or rectangular open pans, one of which is shown at B. At the bottom of the melting, or *blow-up* pans, as they are termed, is a perforated copper worm, and over the worm is a perforated false bottom to keep back any large substance that might be mixed with the sugar. After adding to the sugar a sufficient quantity of water to bring the density of the liquor, when dissolved, to about 44·5° to 46·5° Twaddell, the steam is then turned on, mixing directly with the sugar; whilst being dissolved, bullock's blood—still in some places—and lime water are added to clarify it and neutralize the acid. Mr. FINZELL

Fig. 565.



of Bristol, one of the largest sugar refiners in the world, has patented a modification of the vacuum pan in place of the ordinary melting pans, which he thinks expedites the operation of melting; the sudden expansion of the air confined among the sugar assisting the steam and water in the breaking up and melting of the mass. A movable false bottom is placed over the worm to allow a space for the water between the sugar and the heating surface, and to keep back any extraneous matter. Messrs. Finzell and Aspinall have also recently patented a new form of pan for melting sugar, in which the sugar is suspended near the surface of the water in such a way that, as it becomes dissolved, it falls by reason of the greater density of the solution to the bottom of the pan, leaving the next stratum to be acted on by water not so saturated with sugar; whereas, if the sugar lies at the bottom of the pan, the water in immediate contact becomes thoroughly saturated, and, remaining at the bottom by reason of its density, retards the dissolution. This is, however, compensated for by a large stirrer, universally used in blow-ups. On emptying the hogsheads, *et cetera,* a portion of sugar is left behind sticking in the crevices of the staves; this is removed by placing the hogshead in a *steamer*—when, the steam being turned on for a short time, all the sugar is washed out of the hogshead, and drops mixed with the condensed steam to the bottom, from whence it is conveyed to the melting pan.

From the melting pan, B, the liquor is drawn off to the bag filter, C, similar to those described before for the cane juice. The liquor then runs into the receiving cistern, D, with a coil of copper steam-pipe at the bottom to increase the temperature previous to entering the charcoal filters. The charcoal filters, one of which is shown at E, as generally used in refineries, are cylindrical vessels of cast-iron or copper, about five feet diameter, and twenty to thirty feet high; the greater the depth of charcoal the liquor has to pass through, the less coloring matter is left in the liquor. The filters are furnished with a perforated false bottom, a blanket being spread over it to prevent the charcoal from passing through with the liquor. The tops are generally closed, to admit of a head of liquor above the charcoal to accelerate its passage through the filter, a manhole being cast in the cover to let in the charcoal, and another at the bottom to get it out when required to be changed. From the filters the liquor runs into a cistern, F, placed on the basement or *fill-house* floor, from which it is drawn up into the granulating pan, G. A vacuum pan is used for this purpose similar to the one before described for granulating the sugar from cane juice; only in this drawing the condensation is shown, effected by the injection of cold water into a vessel when it meets the vapor from the pan: this method is adopted when water is abundant, the outlay not being so great. The sugar, when granulated, is let down into the heater, H, by a slide in the bottom of the granulating pan, the sugar requiring the temperature to be increased in order to harden the grain; it must also be well stirred, to mix the grain thoroughly previous to being ladled out into the moulds. This operation of ladling is usually performed in copper *filling-out* basins, into which the sugar is ladled from the heater. When practicable, labor may be saved by raising the pan and heater up to a floor above, so as to draw the sugar off from the bottom of the heater by a slide.

Centrifugal Machines.—If the sugar is intended to be in the form of crystallized, from the heater it is put into the centrifugal machine, which consists of an outer cylindrical case, in which revolves at a very high speed an inner vessel perforated round the circumference, into which the sugar to be dried is placed; the centrifugal action from the velocity causes the sirup to pass through the perforated circumference into the outer case, from whence it is drawn off, leaving the crystallized sugar behind. By this means much time is saved in the draining of the sugar. The same effect is sometimes attained by connecting the bottoms of the moulds to a pipe communicating with an air-pump, when the pressure of the atmosphere acts in the same manner as the centrifugal force; or the sugar is placed in a large box fitted with a perforated false bottom, from which the air is exhausted. This latter plan is often adopted with much success in the West Indian Colonies.

The moulds, I, I, I—Fig. 565—into which the sugar passes from the heaters, are of a conical shape, and usually made of sheet-iron; the lower part or apex of the cone being of cast-iron, with a small hole for the sirup to drain through. They are either painted or galvanized inside and out, to preserve them from rust; they are made of different dimensions, according to the size of the loaves required and the quality of the sugar, and are named respectively—loaves, titlers, lumps, and bastards. From the fill-house the moulds are conveyed to the various floors, which are heated by steam-pipes to a temperature of 75° to 80° Fahr., to facilitate the drainage. The moulds are ranged all over the floors, with the points of the moulds resting on iron or earthenware pots, to receive the sirup drained from them. After standing some time till their own sirup drains from them, fine liquor, consisting of a saturated solution of pure sugar, is poured on the top of the moulds, thus, as it percolates down the loaves, washing away with it the impurities remaining on the sugar, which would otherwise adhere to the surface of the crystals. After this the loaves are taken out of the moulds, the lower end is cut to a point in a nosing machine, as it is called, and the top trimmed off by a machine with revolving knives. The ends so cut off are not of equal quality to the centre of the loaf, and are melted over again. The loaves are then papered up and further dried in a stove, J, which is heated by steam pipes at the bottom, and fitted with shelves on which the loaves are placed. After drying they are ready for the market. The moulds are lifted from one floor to another by a machine called a mould-hoist, which is driven by the engine. The mould-hoist, as made by Messrs. Pontifex and Wood, is shown at K, K, and consists of two endless pitch-chains working over pulleys fixed under the fill-house floor, and at the top of the house; between these chains are slung cradles, with rings adapted to the various sizes of moulds used in the house. Holes are cut in the various floors sufficient for the passage of the moulds, which are readily placed in and taken out of the cradles as they pass up or down. The cradles are slung upon axes, so that the moulds turning over the drains remain in the same position, thus preventing the risk of accident in case the attendant should omit to take them out as they pass him, in which case they only make the circuit with the chain, and are taken out the next time they come round to the floor on which they are required.

The charcoal, after it is removed from the filters saturated with coloring matter, is dried, and then reburnt. The retorts of cast-iron or kilns of clay are so constructed that the charcoal, when at a red heat, does not come in contact with the atmosphere, which would destroy it. The charcoal reburners, as arranged by Messrs. Pontifex and Wood, are shown in Vol. I. of this work, page 340, under the article Bone-black. L is a cistern for water, and M a cistern for fine liquor, a pipe from which runs down the house, with a cock at each floor. This is used for washing the impurities off the sugar crystals in the moulds, as before described.

M. Alfred Fryer of Manchester has been for some time at work with apparatus which, if successful, will greatly alter the sugar manufacture. He believes it is a wasteful mode of procedure to attempt to purify sugar in the colonies, even to the smallest extent, the facilities for doing so here being much greater. His method is designed to dry the cane-juice rapidly down into a hard concrete, and so to import it into Europe. In the concrete form, and almost free from molasses, it will not decompose, and the enormous waste of more than half the sugar will not take place, the loss in the European refineries being considered large at six or seven per cent.

Beet-root Sugar.—In Germany and France cane sugar is extracted in large quantities from the beet-root. The beet-root is a biennial plant, native to the South and South-west of Europe. It appears to have been introduced into the Netherlands during the possession of that country by the Spaniards, and to have thence passed into France, Schleswig-Holstein, Germany, Sweden, England, *et cetera*. There are many varieties of the beet, but that specially prized by the beet-root sugar manufacturer, and therefore chiefly cultivated in those countries where this branch of industry is pursued, is the Schleswig beet, or white beet—*Beta alba*—called also from its qualities the sugar beet. When the leaf-buds appear above the ground, the leaves thrown off sometimes rise very high before spreading; sometimes they spread almost immediately above the surface of the ground. This variation, which is partly hereditary, partly conditioned by soil and other circumstances, gives rise to a considerable difference in the quality of the sugar which is extracted. For as the thick and upper end of the tapering root is, during the growth of the plant, projected a little above the surface of the ground, the exposed portions are acted upon by the light, and the otherwise white root is thereby turned green owing to the formation of chlorophyll. But where the leaves spread out on emerging from the ground, the root is shaded and preserved from such colorization. The Quedlinburg beet has a shade of red on its outer coating, and a species of a yellow variety has been recommended on account of the greater quantity of sugar that exists in its juice. The root of the beet contains water, cane sugar, vegetal fibrin, and fat, gum, coloring matter, pectin, together with the carbonates, chlorides, sulphates, nitrates, phosphates, oxalates, malates, *et cetera*, of potassium, sodium, iron, lime, and magnesia. The water varies from eighty to eighty-eight per cent. of the whole root. The solid matter—twelve to twenty per cent.—contains from four to six per cent. of vegetal fibrin; the remainder is cane sugar, with the other constituents. The length and straightness of the healthy beet points to a deep soil as the one appropriate to its cultivation, while the large quantity of water limits its growth to tolerably moist localities. An over-rich soil, however, is harmful, on account of the introduction into the plant of too much of the mineral constituents. Two or three of the seeds of the beet-root are set by means of a hand hoe, about a quarter of an inch below the surface, at regular intervals of between thirteen to sixteen inches, and covered with earth. If, in consequence of a short heavy rain succeeded by dry weather, the surface of the earth becomes so hardened that the young plants are suppressed, and the prospect of a sufficient crop is lost, the land should be reploughed, and a fresh sowing performed. The amount of sugar contained in the beet varies with its size, the smaller plants containing more sugar in proportion than the larger ones.

It has been found that—

Beets	weighing	$\frac{1}{4}$	pound	contain	13	per cent.	sugar.
"	"	$\frac{1}{2}$–1	"	"	11–12	"	"
"	"	2	"	"	8–10	"	"
"	"	3	"	"	6–7	"	"

Nevertheless, on account of the greater mechanical trouble of working the smaller beets, the larger are esteemed most. The tapering point of the root and the thick and higher end also contain less sugar than the central portions; this is especially the case with the thick end when it has grown above the ground and become colored by exposure to the light. During the growth of the plant, which lasts about four or five months, the soil must be turned by the hoe four or five times, the first hoeing being performed soon after the appearance of the young plant. The following rotation of crops is said to be favorable for the cultivation of the beet—1. Barley or wheat—with manure. 2. Beet. 3. Oats—three fields being kept under crop. If four fields be employed, clover may be advantageously introduced after the beets.

The beet, as before stated, is a biennial plant. During the first year of its life the root is developed to its full size, and secretes the whole amount of sugar which, in the natural life of the plant, furnishes the material for the growth and maturity of its upper part. It follows that when the plant is cultivated for its sugar, it is for this purpose ripe when its first year's stage of development is complete. The time required for this depends upon that of the sowing, and upon the seasons. Its criterion is the commencement of death in the leaves. When ripe the beet-roots are dug out, the mould gently shaken off, and the heads cut off, together with as much of the root as shows the presence of leaf buds. As the action of light is detrimental even to the exhumed roots, the latter must be covered quickly. If the quantity be small they may be covered with the leaves which have been cut off. It is more usual, however, to pile them in heaps on the ground, to hinder the evaporation of their water, and to protect them from light and frost by covering the heaps with a thin layer of earth. These mounds are sometimes sprinkled with water, which is taken up by the roots, restoring to them their plumpness and crispness which they have lost in a dry season.

The amount of beet root obtained on a given space is, according to **BOUSSINGAULT**, in—

	On a hectare; kilogrammes.	On an acre; lbs.
Pas de Calais	31,400	27,664
Aisne	25,500	22,770
Nord	35,000	31,226
Somme	24,500	21,859
Enre et Loire	8,500	7,570
Seine et Oise	27,250	24,312
Cher	38,000	32,904
Seine et Marne	30,000	26,766
Meurthe—Roville	17,500	15,613
Mean,	26,405	23,508

Some roots were examined by **RAGSKY** and **CORENWINDER** for their specific gravity—

By RAGSKY.

	I.	II.	III.	IV.	V.	VI.
	From Venice.	Olmutz.	Hungary.			
Specific gravity	—	—	—	1·050	1·042	1·056
Sugar	10·70	—	—	9·4	9·8	8·73
Salts	0·92	0·87	0·85	1·76	0·94	—

By CORENWINDER.

	VII.	VIII.	IX.	X.	XI.	XII.
		From North of France.				
Specific gravity	1·048	1·044	1·045	1·038	1·045	1·037
Sugar	10·00	9·40	8·76	7·90	9·45	8·01

PAYEN gives the following as the chemical constitution of beet root:—

	Per cent.
Water	83·5
Sugar	10·5
Cellulose	0·8
Albumen, casein, and nitrogenous matters	1·5
Salts, &c	3·7
	100·0

Under salts, *et cetera*, are included malic acid and gum, nitrogenous substances, fatty matters, aromatic substances, coloring matters, essential oil, chlorophyle, malamide, oxalate and phosphate of lime, phosphate of magnesia, chloride of ammonium, silicate, nitrate, sulphate, and oxalate of potassa; oxalate of soda, chlorides of sodium and potassium, pectates and pectinates of lime, potassa and soda, sulphur, silica, oxide of iron, *et cetera*. The sugar is entirely in the state of cane sugar.

It has been shown, however, that ammoniacal salts do not exist ready formed in beet juice, but are the product of decomposition eliminated, especially when lime is added.—*Michaelis.*

Lactic acid is readily formed by the decomposition of beet root sugar in its juice, and some persons find mannite, although others are not able to do so. A gummy substance is also produced, probably similar to that found in cane sugar refineries, when the sugar has been too long boiled and worked with.

The beet is grown in temperate climates, and it requires a good deal of moisture.

BOUSSINGAULT gave the following analyses of French beets:—

Where grown	Time of taking from ground, *et cetera.*	Per cent. of dry matter.	Water.	Sugar.	Ligneous fibre and albumen.	Pectin?
Botanic school,	Aug. 2.—Roots small,	9·5	90·5	5·0	4·5	added to the lig. matter
	Sept. 1.—A root of 1100 grammes = about ½ lbs.,	7·4	92·6	4·2	2·5	1·0
	Sept. 1.—A root of 460 grammes = about 1 lb. 2½ oz.,	9·4	90·6	5·0	2·8	1·6
	Sept. 7.—Root, 700 to 800 grammes,	10·0	90·0	7·3	1·9	0·8
	Young root of 0·3 grammes = 4·6 grains,	13·7	86·3	5·9	4·4	3·4
Garden of M. Brongniart,	Sept. 26.—Root from 80 to 100 grammes = 3½ oz.,	16·1	84·9	10·0	3·3	1·8
	Oct. 9.—Root, 150 grammes = about 5 oz.,	14·1	85·9	—	—	—
Vigneux,	Sept. 23.—Root, 500 grammes = 1 1-10th lb.,	16·9	83·1	11·9	3·2	1·8
	Sept. 23.—Root, 700 grammes = 1½ lb.,	13·0	87·0	8·6	2·7	1·7
Grenelle,	Aug. 7.—Root, 300 grammes = 6-10ths lb.,	15·5	84·5	8·9	6·6	to preceding
	Aug. 11.—Root, 600 grammes = 1⅓ lb.,	12·6	87·4	8·2	2·8	1·6
	Aug. 30.—Root, 1 kilogramme = 2 1-5th lbs.,	13·1	86·9	8·6	3·1	1·4
	Beet in flower, 200 grammes = about 4-10ths lb.,	16·5	83·5	9·8	3·3	3·4
	Beet of two years in seed,	5·5	94·5	0·0	2·5	1·1*
Roville, Meurthe,	White beet of Silesia,	15·8	84·2	10·6	3·1	2·1
Analysed by M. Braconnot.	Leaves of the beet,	6·4	93·6	1·3	3·6	—†

* Add 0·9 of nitre. † Add 1·5 nitre; the albumen added to the sugar.

The following analyses of ashes of beet are by Way and Ogston :—

	Yellow globe.		Long red.	
	Bulb.	Leaf.	Bulb	Leaf
Potassa	23·54	8·34	29·05	27·53
Soda	19·08	12·21	19·05	5·83
Lime	1·78	8·72	2·17	9·06
Magnesia	1·75	9.84	2·79	9·10
Oxide of iron	0·74	1·46	0·56	4·48
Carbonic acid	18·14	6·92	21·61	6·11
Phosphoric acid	4·49	5·89	3·11	4·39
Sulphuric acid	3·68	6·54	3·33	6·26
Chloride of sodium	25·54	37·66	14·18	29·85
Silica	2·22	2·35	4·11	1·35
	99·96	99·93	99·94	99·96
Per cent. of ash	1·02	1·40	1·00	1·91

One ton of beets they calculate, removes from the soil :—

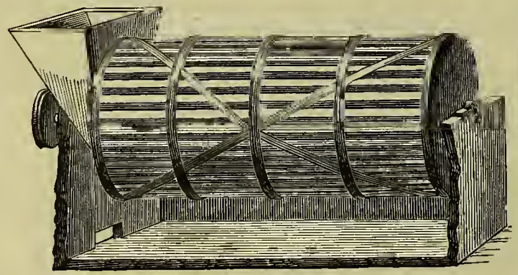
	Mean of three specimens of bulb. Pounds.	Mean of three specimens of leaf. Pounds.
Potassa	4·99	7·86
Soda	3·02	2·52
Lime	0·41	3·31
Magnesia	0·43	3·27
Oxide of iron	0·12	0·52
Phosphoric acid	0·66	1·94
Sulphuric acid	0·65	2·20
Chloride of sodium	5·29	12·82
Silica	0·54	0·76
	16·11	35·20

It has been found that beet with a large amount of juice containing many salts, gives little sugar; either the sugar is not formed, or it is combined with the salts and rendered useless. Manures with a large amount of soluble salts must therefore be avoided; farmyard manure, for example, must not be used in large quantities. Neither a very wet soil nor a very dry one suits the beet root. The Silesian beet is most admired; its juice has a specific gravity of 10° to 15° Twaddell—105° to 107°—and is very pure. It is not a large root.

The amount of juice obtained is from seventy to eighty per cent. of the beet.

The roots, after their extraction from the earth, have to be cleaned and the bruised or diseased portions extracted. For the first purpose they are brought into a horizontal cylindrical cage, which rotates round a horizontal axis, and is turned by machinery.

Fig. 566.

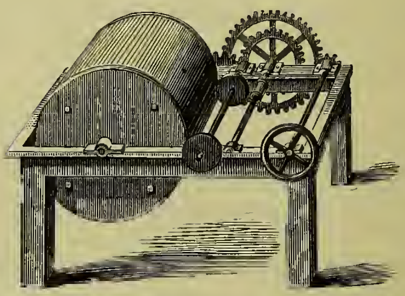


After washing, the roots are examined by women and the unhealthy parts cut out, the smaller side-roots cut off, *et cetera.*

In order that the greatest quantity of juice may be extracted, the roots have to undergo a thorough trituration, the purpose of which is to destroy the cells and other texture, and to allow the free escape of the juice. The accompanying figure shows the construction of a trituration mill of this kind.

The macerated beet-root appears as a white thin emulsive liquid, and contains naturally the whole of the constituents of the root. The soluble portion is separated from the insoluble by pressure. Woollen, linen, or, for the reason mentioned in the manufacture of cane sugar, cotton cloths or bags are employed to hold the juice. When cloths are used the process of *packing* is as follows :—A plate of iron of the size which the cake is destined to have is placed upon the press-table—see below. Around this plate a movable wooden frame is placed, of the appropriate depth. The frame and plate are covered with the cloth, which is smoothened into the edges and corners of the box so formed; the corners of the cloth being of sufficient length to cover the box again when folded back. A measure of the crude juice is then poured upon the cloth smoothened down by the hands, and the corners of the cloth are folded back upon it. The wooden frame is then removed; another plate is placed upon the top of the first cake, the frame adjusted round it, and the same process is repeated. In this way a pile of cakes, inclosed in cloths, is formed, alternating with iron plates. Sometimes, instead of iron plates, a disc of plated osier, or a series of rattan canes lightly bound together is used. The latter contrivances are less likely to break the bags when the pressure is applied, but the juice is not so perfectly expressed as when metal ones are employed. When bags are used they are filled with the juice, the mouth squeezed together, and the whole turned over upon the plate, so that during pressure the mouth is held together.

Fig. 567.



The piles of cakes are next submitted to pressure, usually that of a hydraulic press. The piston of the press is made to descend and to squeeze the pile between itself and a firmly fixed metallic slab, rather larger than the cakes. The surface of the press table is nearly on a level with the top of the slab. The press table is surrounded by a rim, through one part of which a hole is cut, connected with a pipe for carrying off the juice. It has been proved that the best presses leave at least twelve per cent. of the theoretically extractable juice in the cakes. A portion of this may be recovered by steeping the cakes which have undergone the first pressure, in a shallow vessel of water, or submitting them to the action of steam, and subjecting them to a second pressure. But even then by no means the whole of the sugar is separated. Moreover, the greater dilution of the juice so produced increases the expense of its subsequent working. Perhaps the centrifugal drying machine may find an application to this end; or perhaps the passing of long bags of the juice through cane crushing-mills might extract the juice more effectually. But the importance of the perfect separation of the sugar is not of so much moment as is the case with canes, because the spent cakes are generally used in beet-root sugar manufactories as food for the cattle employed on the estate, and their value for this purpose is greater the more sugar they contain.

An exhaustive method for obtaining the juice from beets has been proposed, in which the roots are sliced and macerated without destroying the integrity of the slices. The weak juice thus extracted is employed for macerating a fresh portion of slices, and so on until the extract is sufficiently strong for defecation and filtration.

Probably on account of the greater quantity of albuminous matter contained in the beet over that in the cane; in part, also, on account of the greater dilution of the natural sirup—the oxidation and fermentation of the former proceeds more readily. Hence extraordinary care must be taken not only to submit the extract from the beet as speedily as possible to the subsequent operations, but the press table, *et cetera*, must be thoroughly cleaned after each pressing, and the bags or cloths perfectly purified.

The processes for defecating the juice of the beet-root, are so analogous to those already described with the juice of the cane as to need no special description. The scum is submitted to pressure in a screw press, in order to separate the juice which it retains mechanically.

The employment of bone-black, also, resembles almost completely its use with cane sugar. In the beet-root sugar manufacture, however, the filtering cylinders have usually a longer and narrower form than is the case with cane sugar.

Perfectly pure sugar made of beet cannot be distinguished from perfectly pure sugar made of canes; but the imperfectly purified sugars may be distinguished—first, by the analysis as shown in the composition of the juices; and second, by the taste; which is in the case of the beet-root bitter and unpleasant; in the case of the cane sugar extremely sweet, with a pleasant vegetal aroma.

When beet is taken from the ground, it is used at once for sugar; if not used it rapidly germinates, and the sugar diminishes. For this reason SCHUETZENBACH introduced the method of slicing the beet in small pieces and drying it rapidly. When dry it may be preserved. When this plan is adopted, the manufacture may be carried on during the whole year, instead of during a few months only, or from October to March.

By the process of SCHUETZENBACH three hundred kilogrammes of beet are dried every twenty-four hours on a square metre, losing eighty to eighty-four per cent. of their weight. When used it is dissolved into a juice containing thirty-eight to forty-two per cent. sugar at 42° Twaddell, so that there is much less of water to be evaporated than with the green juice. The dried beet is macerated in a closed vessel.

100 kilogrammes of beet give 18 kilogrammes dried beet.

	Francs.
40 hectolitres of coals, at 1·50 francs for a hectol., dry, 40,000 kilogrammes of beet	60
20 days of a woman's wages at 80 cents	16
14 days of a man's wages at 1·5 francs	21
Interest on the kiln—costing 14.000 francs—for 9 days, at 7 per cent.	11
	108

100 kilogrammes of dry beet cost 11 francs 11 cents.

M. SCHUETZENBACH has now made an immense establishment in Gallicia. It is calculated to produce forty million kilogrammes of sugar yearly. There is a central sugar refinery and fourteen drying establishments in a circle of seven leagues, in order not to carry the wet beet far. He obtains a dry produce containing fifty per cent. of sugar. It is dissolved in closed vessels, and gives a juice of 52° Twaddell. He obtains six per cent. of sugar from the root. Such an establishment keeps a large circle of ground occupied.

It has been said that it is better to cut the beet into cubes. This plan is not adopted at Waghæusel, one of the most complete establishments, and certainly their slices being thin must dry readily. The plan adopted there is to dry for preservation; this is done in six hours on the wire gauze. Then when making the solution, it is at first obtained at 32° Twaddell, and boiled in vacuo down to 41·5 Twaddell, lime water added, boiled half an hour to remove ammonia, and kept alkaline with lime.

The establishment of Waghæusel, near Carlsruhe, employed in 1855 three thousand people; twelve hundred of these were in the drying department. One drying department was at the works, and six others at different distances. The works covered twenty-five morgen of land—about twelve acres. There were in it one hundred horses, one hundred cattle, and from thirty to forty pigs. A hundredweight of raw roots cost the establishment seven-pence. There were nine cylinders for refined sugar, and thirteen for commoner, twelve feet by six. There were twenty infusing vessels, twelve to fourteen feet deep and seven wide. The dry beet contained forty-six to forty-seven per cent. of sugar. Five per cent. were lost in making; by the old way the loss averaged eleven per cent. The capital was about eight million francs.

Maple Sugar.—In the Western State of North America, a great portion of the sugar required for home consumption is extracted from the maple. The season at which the collection of the juice takes place is the early spring—February, March, and April, when a light snow is on the ground. The trees most fit for tapping are those which have reached the age of twenty to thirty years. At the south side of such trees two or more holes are bored about four or five inches apart, three-quarters of an inch in diameter, and about two feet above the ground. The holes run radially into the tree, and are inclined upwards, penetrating the inner white bark to a depth of about half an inch. Into these holes tubes of elder-wood are inserted. The upper portion of the part of each tube which is in the tree is slit off, so that it forms a semicylindrical canal or trough. Troughs are placed below the projecting ends of the tubes to receive the juice as it flows out. The average yield of a tree is about one quart in twenty-four hours. A tree may be tapped for twelve years in succession, the average yield being between two and three quarts annually. The crude juice is usually boiled down without defecation or filtration in copper cauldrons, which may contain fifteen or eighteen gallons. When the examination of the concentrated juice shows incipient crystallization, it is poured out into shallow moulds, about two inches in depth. When set, the sirup is usually ladled out of a depression made in one portion of the cake. This maple-sugar sirup, which corresponds to the molasses of cane-sugar, is, however, more highly prized than the sugar itself; it has a delicate aromatic smell and taste, and is greatly sought for making confectionery. The sugar sells at the rate of fourpence per pound. Some years ago enough cake maple-sugar was manufactured in the State of Vermont to inclose the whole State with a wall of sugar eight inches high, and eight inches in thickness. The North American Indians push the evaporation of the juice rather further than the whites, and after the removal of the sirup, the cakes are chopped up for the market.

SUGAR OF STARCH AND WOOD. — Crystallizable sugar is converted by boiling and by acids into glucose or grape sugar, a substance difficult to crystallize. Sulphuric acid converts cellulose, inulin, starch, sugar of milk, straw, sawdust, and such materials, into dextrin and sugar. BRACONNOT obtained from 20·4 of rags 23·3 of dry sugar. Cotton and linen being nearly pure cellulose, would give more than sawdust; about one hundred and forty parts of strong acid are used to one hundred parts of cellulose of rags, cotton, *et cetera.* The change is at first into dextrin—see STARCH—then into the sugar.

Sugar is made from starch by boiling it with water acidulated with one per cent. of sulphuric acid. The conversion takes place in half an hour. The amount of starch is about fifty per cent. of the water. At the same time the quantity is varied, as given by KNAPP that two and a half of sulphuric acid is used to one hundred of starch, and three hundred to four hundred of water. Makers are not precisely agreed as to the time, but it is different according to different degrees of solution. The sulphuric acid is removed by lime. The juice, clarified, is boiled down to 105° Twaddell, and crystallized in flat vessels. Crystallization commences in about a fortnight. The sugar is then drained and dried. This sugar is seldom sold as such. It is manufactured for conversion into alcohol.

The conversion of cellulose and starch into sugar, by the action of sulphuric acid, giving to them some of its water, may be better understood by examining the composition of both, as already given.

CAUSE OF THE LOSS IN THE MANUFACTURE OF CANE-SUGAR.—*Decomposition of the Juice.*—The albuminous matter in the juice is the chief if not the only cause of its rapid decomposition, and this is promoted by a heat which is not less than 80°, as the liquid flows from the crushing mills. Lactic acid in the case of beet juice is abundantly formed, and a viscous substance which has no sweetness. At the same time, also, there is formed a little mannite. An enormous loss of sugar is known to occur from this change of the juice. The one to two per cent. of alkaline salts can scarcely be said to act prejudicially to any extent. There is no known way of removing them.

To prevent the decomposition of sugar, especially in the case of Colonial juice, in warm climates, it is important to use an antiferment. PROUST proposed sulphite of lime in 1810; and DUBRUNFAUT took a patent for using sulphurous acid in 1829. MELSENS of Brussels has lately proved the great value of bisulphite of lime in the manufacture of beet-root sugar. The use of this is becoming general for beet-root. It would, no doubt, be found still more valuable in the Colonies, if no unlooked-for harm was occasioned; although care must be taken not to send the sugar over with sulphites in it. The bisulphite of lime resists the coloring of the juice, and even removes some of the color. Acids readily remove the color of sugar; but such color returns as soon as neutralization takes place. MELSENS believes that by means of this salt he will be able to reduce the molasses so much, that he will not remove the salts in solution in it as now, but by taking out ninety per cent. in a crystalline form, he will return the most of the salts to the earth. The small amount of molasses left could be returned to the pressed out beet before using it as food for cattle. The bisulphite of lime does not destroy the quality of the beet as food. LUDERSDORFF prefers sulphuric acid, afterwards to be neutralized by lime.

It is well to add that a French commission examined the action of bisulphite of lime on cane juice in Guadaloupe, and found that the amount of good well-grained sugar was diminished by it. If they used it as acid, as some do, it is not surprising.

KUHLMANN proposed to prevent the decomposition of sugar by adding an excess of lime, and then throwing it down with carbonic acid. This is again brought forward by M. ROUSSEAU. Three to four times the usual amount of lime is added, making a sugarate of lime; when the juice has reached 131° Fahr. the lime is added, mixed with six times the amount of water; the temperature then is raised to 180° or 190°, and the liquid filtered. Carbonic acid is added, a voluminous precipitate takes place, and the juice is now put on the charcoal filter without removing the chalk. M. ROUSSEAU had it brought before a commission of the French Academy, which reported a favorable result, but considered that the alkalies would act injuriously on the compounds of lime and organic matter not precipitated. To avoid this ROUSSEAU adds ammonia, which is converted into carbonate. The carbonate of ammonia decomposes the combination of the lime, and carbonate of lime is thrown down, leaving ammonia free. But this addition of ammonia is no improvement, and indeed the whole objection is a most uncertain one.

KUHLMANN believes that the free alkaline salts are hurtful, but has found it impossible to remove them by means of strong acids, or by sulphate of magnesia, sulphate of ammonia, or chloride of ammonium. He prefers phosphate of ammonia.

This process—one cannot speak for the phosphate of ammonia, but only for the carbonic acid—is a good deal used in France.

MAUMENÉ says that if lime is added in quantity sufficient to form three of lime and one of sugar—$3\ CaO\ C_{12}\ H_{11}\ O_{11}$—the sugar is preserved, and nitrogenous matter falls with the lime. However this may be, if boiled with the lime the color is rapidly deteriorated.

Precipitation.—Attempts have been made to precipitate sugar from its solutions. **DUBRUNFAUT** and **R. DE MASSY** have a process depending on the union of sugar with baryta. Caustic baryta is added to the sugar till it is all thrown down. A pure compound of baryta and sugar falls, and this is decomposed by carbonic acid. It is not at all proved that all the sugar can be thrown down in this way; it is said only to be done at a boiling heat. **NICKLÈS** says it cannot be done with uncrystallizable sugar.—See further in accounts of *Patents*.

USES, PHYSIOLOGICAL EFFECTS, AND IMPURITIES.—Sugar exists in the juices of many plants, and is in part the food of many animals. As an article of food it has highly fattening properties, and as such it must be considered as serving mainly for the production of warmth in the body. Animals which eat it appear sleek and comfortable, and it tends to promote digestion. At the same time there are many persons who cannot use it as food to any great extent, on account of its inclination to produce acidity. The negroes, and even whites, who suck the sugar cane are not found to be troubled with these symptoms, whilst the teeth of the negro never suffer from the constant use of the sweetest liquids. Such, however, is not the case in England, where a great amount of sugar is found to be hurtful to the teeth. It is perhaps scarcely correct to say this of sugar in the diet, as it is not well known that the same effects would be produced by sugar used in abundance—in pies, for example—as would be produced by sugar taken alone and long retained in the mouth. Persons engaged in sugar works are in the habit of eating sugar very frequently. With some it is a part of their duty, as the value is to some extent measured by the taste; but whether as a duty or a pleasure, such persons are almost invariably doomed to lose their teeth at an early period. It may be said that sugars, until dried or thoroughly crystallized, have a certain amount of acidity in them; but this is in general too small to stand as a reason: much more acid is taken in other species of food. There can be no doubt that sugar in large quantities peculiarly affects the digestive organs, and causes also a distinct taste, other than sugar, to be perceptible some time. The cause may be that as an article of food it does not associate well in large quantities with the food used in this country. But, again, its valuable qualities are many, and the amount fitted for individuals must be found by experience.

The excessive use of sugar, that is, to the extent, with a healthy man, of about a pound per day, produces effects not apparently much studied. One effect is a tendency to giddiness, without any observed additional inconvenience. It is possible that this may arise from the large amount of carbonic acid generated during its decomposition, causing at the same time frequent eructations.

When the throat is irritated, a solution of sugar slowly flowing over the surface prevents irritation and allays coughing. Sugar and treacle are valuable for covering burns, acting chiefly, as Mr. **CROMPTON** of Manchester believes, as non-conductors of heat. It is sometimes used in a powdered state for ulcers or rather proud flesh, and for specks on the cornea. It has a considerable power of reducing metallic oxides, and has been used as an antidote for poisoning by metallic salts, such as those of copper; mercury, silver, gold, and lead may be included; but this action has been referred more to its physical than to its chemical properties. It is highly antiseptic, no doubt, because it covers from the atmosphere. It is much used in pharmacy for imparting flavor to bodies, and to conceal taste. It is also found useful for giving form and consistence to some medical substances. It is employed as a medium of bulk to convey smaller substances, as in opium, lozenges, *et cetera*, and notably so by the homœopathists, whose medicines may sometimes be distinguished from sugar. Many animals delight in it. Horses put their noses into the sugar bags, and even suck them, whilst the fowls fight for the fallen pieces.

Sugar is also employed for fermentation. Indeed, properly speaking, it is the only thing used for fermentation; but sugar from the cane, and still more the less crystallizable portion, is now considerably used. It has been employed for the purpose of making oxalic acid by oxidation with nitric acid; but starch or cheaper substances are more commonly employed. Enormous quantities are used in preserving fruits. Preserved fruits are becoming daily more and more accessible and more used. Formerly fruit was preserved only by such careful and well-to-do housewives as could spend some considerable time and money on the luxury. Now the conservation forms a branch of industry or manufacture. Marmalade and preserved oranges are sent from Scotland in great quantities, and are everywhere prepared. Preserved fruit is also sent from various parts of Europe, especially the shores of the Mediterranean, and it has begun to appear at our dessert tables after arriving from the East and the West Indies. England, as usual, takes up this manufacture with great vigor. One house made a small experiment last year with thirty tons of preserved plums, and finding it successful made next year a hundred tons. The preserves were of an excellent kind, and cheaper than those made by the usual methods in smaller quantities.

The amount of sugar used in the form called sweetmeats, comfits, and bonbons is very great, and more so on the Continent, according to accounts, than here. At the same time, although one finds in France, Germany, and Italy some very handsome confectionery shops, it strikes the Editor that the amount of comfits in them is very small, and the variety very limited. The sugar may be pure and unadulterated with arsenic and sulphate of lime, or any other noxious or poisonous substance; but the shops seem to depend a good deal on their sale of beverages, and in some places on their restricted number. No country offers such great varieties of excellent sugar sweetmeats as England, or in such rich diversity. In China the variety is said to be very great. The only fault in England is that there exist so many qualities to suit the purses of every man, rich and poor. The inferior qualities are mixed with flour. This, of course, diminishes the sweetness. This would be a small evil, if the makers did not sometimes use instead of flour sulphate of lime or plaster of Paris. Even this, however, is innocent in comparison to the coloring matters used at times. Sweetmeats are colored by ignorant people with common paints of any kind that come in the way. These are painted roughly on the sugar. Some of them contain copper, some arsenic and copper, and some lead. Several cases of death have occurred from the use of such substances; and there can be no doubt of the propriety of a surveillance over the manufacture or sale of articles liable to be so abused. The best confectioners use only innoxious colors, and these vegetal.

The unfiltered sugar, or Muscovado, as it comes from the Colonies, contains many impurities, and should never be used. Many peculiar species of beetles are found in it. One especially infests abundantly all sugar-houses. But the *acarus sacchari* is the animal that, of all others, is the most to be avoided; it is not found in filtered sugar. It is an animal somewhat like an itch insect, and a drawing would not be pleasant in an article on sugar. The grocers' itch is in all probability produced by the handling of Muscovado sugar, and the attacks of this insect. Dr. Hassall advises the use of refined sugar only. The Editor is able to state that, in Lancashire at least, purified or filtered sugars, of various shades of color, are everywhere to be had, and they are as free from insects as the purest white lumps.

Sugar itself for domestic purposes is not now adulterated, or very rarely. There was a time when sand was used to adulterate the brown qualities; but such a practice would not now be tolerated for a moment. A very ingenious adulteration came into vogue for a while; but the Editor believes it is not resorted to now. It was the custom of using starch, or starch made into gum. When this is used in tea or coffee it is not readily distinguished from true sugar. If starch is employed it is readily found by dissolving the sugar in cold water, in which the starch is not soluble. If British gum be used it is less easily detected; it has small granules, not hard and crystalline like those of sugar, and is soluble in cold water. It also becomes gummy in drying, instead of becoming sirupy, and then crystalline like sugar. This adulteration cannot be made with pure white sugars. A microscope assisted by an ordinary good taste is perhaps the best guide to its discovery. The most general use of sugar is for sweetening tea, coffee, and chocolate; but it is also largely used in sweetening mixtures of strong drink, as well as in numberless articles of cookery. Its abundant introduction into Europe has changed the whole system of cooking and must have largely assisted in rendering food pleasant in an age when the arts of peace have somewhat taken away the violence of appetite which is connected with rude times, and is satisfied more with quantity than quality. For the poor especially is this remarkably true.

A LIST OF SOME OF THE LATER MORE INTERESTING AND CURIOUS INVENTIONS RELATING TO SUGAR, WITH REMARKS:—

1845.—James Johnston patents an ingenious plan of emptying a vacuum pan without destroying the vacuum by a pipe twenty-five feet long. He also has the sugar running down an inclined plane whilst in the vacuum.

Fredrick Gye presses sugar into suitable forms for use.

1846.—Richard Wright patents exposure to hydraulic pressure and steam.

1847.—James Johnston patents polygon shaped sugar moulds, cast-iron crystallizing pots coated with tin, zinc, or enamel. The latter would be good if the enamel did not break off into the sugar.

H. K. Claypole.—Saving fuel with two generators like locomotive boilers, heated by a fire that first passes over three open boilers. A current of high pressure steam to make a draught. A hot iron tube heated by steam in the clarifying boiler. A canal in the teache for running out sugar. Galvanized iron coolers. These are for the Colonies.

John Scoffern.—Combined use of lead and sulphurous acid as separately described.

1848.—J. A. Steinkamp patents the use of cotton in small pieces of one-eighth to one-fourth of an inch for clearing sugar.

1849.—John Oxland patents acetate of alumina boiled with sugar at 220° till the acid is removed. The alumina remaining is removed by tannin and a little carbonate of lime.

Reece and Price patent hyposulphites with alumina or acetate, hyposulphite of alumina, and various hyposulphites and sulphides of magnesium to precipitate lead. Also hyposulphites and sulphurous acid to remove the sulphide of hydrogen which has been used for removing lead. The bicarbonate of lime for defecation and many other things.

A. V. Newton.—Bones dissolved in sulphurous acid for completely extracting the crystallizable sugar. Other antiseptics, as mustard, creosote, horseradish, nitrous acid gas, with or without salts of iron or other salts. Tannin, lampblack saturated with creosote, products of the distillation of certain albuminous matter, tars, wood essence of turpentine, aldehyde, and analogous bodies, chlorine combined with oxygen. Separating ninety-seven per cent. of pure sugar by baryta, and decomposing by carbonic acid or sulphurous. Oxide of strontium, it is said, requires a long time; oxide of lead does it imperfectly. The process gives fifty to sixty parts of hydrate of baryta to one hundred of sugar. Still the sugarate obtained contains fifty per cent. sugar, twenty-two baryta, and twenty-eight water. It is decomposed by a solution of twenty-five quarts of water and twenty-eight pounds of sulphuric acid. It may be washed till the solution has the strength of 23° to 31° Twaddell. If lime is used, twenty-eight per cent. is taken. The sugarate is filtered out in TAYLOR'S filter, or in presses warmed to 100°; it contains five equivalents of base to one of saccharic acid.

The baryta does not offer to be cheaper than animal charcoal, and baryta, at least as a soluble salt, is no less dangerous than lead, whilst it is not so easily detected. Several patents have been taken for removing the baryta, but on this point, the last traces excepted, no difficulty has been found.

C. W. FINZELL—Patent to introduce steam to clear the sieve of the centrifugal machine.

1850.—JOHN SCOFFERN makes a valve of elastic material over a perforated tube.

GEORGE GLYNNE grinds sugar with litharge, and makes a saccharide of lead.

Sugar is a very tender substance chemically. It is easily destroyed. It also readily dissolves many substances. As little of any substance should be added as possible, and as little heat should be given and as little motion.

D. T. SHEARS makes loaf sugar at once on boiling down the juice; purifies sugar by alkaline liquids and sulphurous acid gas; uses also lime and a West Indian plant called *wassama.* Puts a *rouser* in the vacuum pan for stirring round.

HERMAN SCHRODER—a combination of revolving discs on pipes heated by steam to evaporate the sugar.

1851.—R. and J. OXLAND.—When acetate of lime is used, remove by superphosphate of lime or lime. Aluminate of lime to defecate, or phosphate of alumina.

R. A. BROOMAN—Centrifugal apparatus in a vacuum pan; centrifugal drum for evaporation; centrifugal apparatus for cleaning charcoal.

1852.—HENRY BESSEMER.—The claims in this patent being nineteen, are too numerous to mention, and so complicated as to require an article for themselves. It is believed that they rather tend to load a refinery with machinery. Invention will rather simplify the machines, or altogether dispense with some of them; but there are good and ingenious thoughts amongst those of Mr. BESSEMER worth studying, although not as yet found successful.

R. A. BROOMAN.—Endless bands for carrying the sugar to be cleansed.

ROBERT GALLOWAY.—Using plumbite of lime instead of lead.

R. W. LIENIER.—Patent for applying sulphurous acid to the pulp of beet-root or cane before boiling it, adding excess of lime. Use of vessels of wood, slate, stone, glazed metal, or earthenware for boiling juice.

WILLIAM MILLER.—For never allowing the sugar to come in contact with metals; evaporating by surfaces formed of cloth or textile fabric.

BROOMAN.—Removing excess of lime by soap.

GERD JACOB BENSEN.—Hot air passed through the sugar to dry it. Crystallized sugar placed in a vacuum pan. Crystals thus got are mixed with a clear sirup produced from refined sugar; the mixture put into moulds aud stored.

In 1852 J. BRANDEIS took a patent for removing lead from sugar by animal charcoal, thus being able to use lead to purify sugar. The Editor believes that the destruction of the animal charcoal soon follows. The oxide of lead, on heating, melts in the pores. This, although possible, would be very expensive.

JOHN ASPINALL proposed lifting the sugar solution in thin layers on an endless band of wire gauze, exposing it to heated air, and drawing off the water. This has not been much used. Even thin layers of sugar may become covered with a pellicle not easily broken. HOWARD'S vacuum pan, by keeping up ebullition, allows no hard surface to prevent evaporation. This, however, may be the germ of something good not yet completed.

JAMES HADDEN YOUNG presses sugar between two unyielding surfaces, one of them perforated; he uses a vacuum. The beet-root system is a similar one, but mechanical pressure is used.

HENRY BESSEMER also proposed contact of warm air, raising the sugar in thin layers on screws or discs instead of on wire gauze, as Mr. ASPINALL. He proposed also in his patents to use wooden troughs for crystallizing, and to moisten the crystals with a deliquescent compound of sugar and chloride of sodium, or with gelatine, glucose, or molasses. He adds, also, the use of hot water instead of steam to heat sugar, and warm air below 212°, and tinned vacuum pans. Tin is too easily dissolved. What might be more useful than any of the above is the enamelled vacuum pan, if such large vessels could be covered with enamel.

GEORGE DIXON has a number of perpendicular tubes, in which is placed the sugar and heated by steam; but there is a want of exposure for evaporation. Perpendicular tubes are found to heat the sugar more equally.

JEAN BAPTISTE MOINIER allows the sirup or liquid to fall over spheres, thus obtaining surface, and he allows it *to descend from amongst the spheres,* and exposed to warm air.

1853.—WILLIAM PIDDING patents hydrate of alumina, or silica, or a mixture incorporated with a fatty acid, and adds a little oxide of iron. He seems to wish to include the impurities of the sugar in a kind of fatty salt or soap. This answers for some liquids, but the iron will not improve sugar.

FRANK CLARK HILLS removes the lead from sugar by filtering through sawdust, or by dissolving it out with nitric or acetic acid. Animal charcoal much treated with acid soon loses its texture.

Lord HOWARD DE WALDEN cleanses crystals by hot air and steam. This is, in fact, bleaching with the atmosphere. Air bleaches many substances, but the Editor has not heard if it has been found to act favorably on sugar.

CONRAD W. FINZELL.—Defecation in vacuo. Not yet proved to general satisfaction to be of any benefit.

MANIFOLD, LOWNDES, and JORDAN—Reducing the cane to sawdust, then dissolving the sugar out by steam. This does not seem the right direction, as the great loss is in reality in the juice; it is not left in the cane.

JAMES MAGELSTON—Atmospheric pressure to remove crystals from sugar. This is in fact equal to a vacuum.

ROBERT GALLOWAY—Removing lead by tannic, gallic, and pectic acids, or the soda and potassa compounds.

JOHN and J. E. A. GWYNNE dry beet on an endless band, in one heated cylinder after another.

JOHN THOMAS WAY—Soluble silica to remove the excess of lime in defecation; filtering through a bed of Surrey silica or sand. This would add another operation, as it is supposed it would still require to be passed through the bag filters.

EDWARD BEANS puts the beating tubes into nis vacuum pans vertically, and filters through a false bottom covered with sand, powdered flint, or road sweepings.

1854.—**CHARLES H. COLLETTE** proposed to defecate with lime and superphosphate of lime.

JOSEPH BOUR evaporates by a series of hollow vessels revolving in sirup and internally heated by steam; very much used, especially in the Colonies.

JAMES WRIGHT makes a centrifugal machine, where the outer case revolves with the inner, and a partial vacuum is formed to help the drainage of the liquid without the air-pump.

JOSEPH NASH adds an air-pump to his charcoal filters; fills the centrifugal machine without stopping.

W. A. ARCHIBALD consolidates sugar by exposing to cold air and agitation.

D. T. SHEARS—Another plan for filling and emptying the centrifugal machine without stopping.

PIERRE ANDRÉ DECOSTER has a patent for cutting up the canes; he then presses and mashes by centrifugal power.

L. WRAY wished to take a patent for making sugar from *Holcus saccharatus*, called *imphee* on the coast of Africa. Refused.

1855.—**R. A. BROOMAN.**—A filter of cotton or other fibre between two perforated plates or frames.

JAMES STEELE says that the pin at the apex of the sugar mould is now inserted to make an outlet for the drainage. He inserts it at first, and draws it out when it is desired. A cavity is thus left which assists in drainage. By the insertion of a pin too large a hole is made.

There are many patents for the mode of cutting up sugar into lumps.

JOHN ASPINALL drives the sugar in at the apex of the cone, burning it out at the top.

C. W. FINZELL'S patent for the use of **NEEDHAM** and **KITE'S** apparatus in the filtering of sugar. It is the combination of grooved plates or planks, with filtering cloth, which is laid between two.

ALEXANDER W. ANDERSON precipitates sulphate of copper by tin, and obtains sulphate of tin for sugar refining; then precipitates tin by lime. Removes tin from the sugar at last by animal charcoal.

GARTON and **PARSONS.**—To treat sugar for distilling they add sulphuric acid, and keep the liquid at 140° for five days, then remove by lime.

STATISTICS OF THE UNITED KINGDOM.—The following, from Messrs. **REID'S** circular, of Liverpool, with alterations, will give some interesting details relating to the United Kingdom:—

Sugar being an article of luxury rather than a necessary of life, the extent of its consumption is affected by the condition of the people as well as by market value, and any increase from the first of these causes is a satisfactory indication of prosperity. Reverting to the early years of the present century, one finds that a long continuation of high prices in addition to periodical privations among the laboring classes gradually reduced the average consumption in the United Kingdom from twenty-two pounds per head in 1801 to sixteen pounds in 1844. A combination of favorable circumstances then arose to cause a reaction; the duties were greatly reduced; production increased; prices ruled low; and an enormous influx of gold commenced pouring into the country, thereby so largely adding to the means of procuring extra comforts and luxuries, that the average consumption per head more than doubled during the last fifteen years.

CONSUMPTION AND IMPORTS.—The following statistical table, made up as far as possible from official returns, will more particularly show the changes which have taken place. The figures for the present year are only approximate, as the return had not been made out when the tables were calculated. The prices and duties quoted are for West Indian Muscovado:—

Years.	Population of United Kingdom	Consumption of Sugar.		Prices and Rates of Duty.			Duties paid on all Descriptions.	Per Head.
		Total Tons.	Lbs. per Head.	Gazette Average Price.	Rate of Duty.	Total per Cwt.		
1801	16,371,554	159,916	22	59s. 5d.	20s. 0d.	79s. 5d.	£3,066,163	3s. 9d.
1811	18,548,476	187,092	23	39s. 8d.	27s. 0d.	66s. 8d.	4,652,824	5s. 0d.
1821	21,302,392	170,612	18	33s. 2d.	27s. 0d.	60s. 2d.	4,188,997	3s. 11d.
1831	24,319,811	203,812	19	23s. 8d.	24s. 0d.	47s. 8d.	4,650,606	3s. 10d.
1841	27,021,949	202,899	17	39s. 8d.	25s. 2d.	64s. 1d.	5,114,390	3s. 9d.
1851	27,721,921	328,581	26	25s. 6d.	13s. 3d. 12s. 0d.	38s. 9d. 37s. 6d.	3,979,141	2s. 10d.
1859	30,000,000	450,000	33	27s. 0d.	12s. 8d.	39s. 8d.	6,000,000	4s. 0d.

IMPORTS INTO THE UNITED KINGDOM FROM 1841 UP TO THE END OF 1859.

	1841.	1842.	1843.	1844.	1845.	1846.
Sugar Raw—	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
Of or from British possessions	4,057,617	3,868,334	4,028,231	4,129,345	4,77 9,317	4,617,509
Of or from foreign countries	261	103	76	98	77,307	602,739
Total of raw sugar	4,057,878	3,868,437	4,028,307	4,129,443	4,856,624	5,220,248
Sugar refined and sugar candy	22	37	19	6	56	18,408

IMPORTS INTO THE UNITED KINGDOM FROM 1841 UP TO THE END OF 1859—*continued.*

	1847.	1848.	1849.	1850.	1851.	1852.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
Sugar raw—						
Of or from British possessions	4,805,489	4,921,332	5,409,209	5,183,097	4,854,506	6,216,341
Of or from foreign countries	974,019	1,220,964	496,478	908,395	1,379,041	682,526
Total of raw sugar	5,779,508	6,142,296	5,905,687	6,091,492	6,233,547	6,898,867
Sugar refined and sugar candy	26,130	46,191	75,137	116,335	338,079	273,991

	1853.	1854.	1855.	1856.	1857.	1858.	1859.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts	Cwts.
Sugar raw—							
Of or from British possessions	5,740,854	5,589,467	4,934,343	5,695,363	5,325,975	5,323,580	5,458,380
Of or from foreign countries	1,531,979	2,439,291	2,319,879	2,065,877	3,064,721	3,775,300	3,552,420
Total of raw sugar	7,272,833	8,028,758	7,254,222	7,761,240	8,390,696	9,098,880	9,010,800
Sugar refined and sugar candy	214,756	303,649	287,520	187,211	329,122	262,460	386,820

UNITED STATES.

CONSUMPTION OF FOREIGN AND DOMESTIC CANE-SUGAR, FOR THE YEAR ENDING 31ST DECEMBER IN TONS.

Year.	Foreign.	Domestic.	Total.
1859	239,034	192,150	431,184
1858	244,758	143,634	388,492
1857	241,765	39,000	280,765
1856	255,292	123,468	378,760
1855	192,604	185,148	377,752
1854	150,854	234,444	385,298
1853	200,610	172,379	372,989
1852	196,558	118,659	315,217
1851	181,047	107,438	288,485
1850	143,045	126,421	269,466

Average increase for the ten years, 6⅔ per cent.

Oregon and California not included.

PRODUCTION OF CANE AND MAPLE SUGAR IN THE UNITED STATES FOR 1850.

	Cane-sugar in hogsheads.	Maple-sugar in pounds.
Maine, ...	—	87,541
Missouri, ...	—	171,943
Maryland..........	—	47,740
Alabama, ...	28	—
New Hampshire,....	—	1,292,429
Vermont, ...	—	5,149,641
Massachusetts,......	—	768,598
Connecticut,.......	—	37,781
New York, ...	—	10,310,764
New Jersey,........	—	5,886
Pennsylvania,......	—	3,178,373
Virginia, ...	—	1,223,905
North Carolina,.....	½	27,448
South Carolina, ...	150	200
Georgia,...........	1,273	50
Florida,............	1,741¼	—
Mississippi,........	278¼	—
Texas, ...	7,017	—
Arkansas, ...	—	8,825
Tennessee, ...	—	159,888
Ohio,..............	—	4,521,643
Michigan, ...	—	2,423,897
Indiana, ...	—	2,921,638
Illinois, ...	—	246,078
Iowa, ...	—	31,040
Louisiana,..........	262,486	—
Kentucky, ...	—	386,233
Wisconsin,........	—	661,969
Minnesota,........	—	2,950
	272,974	33,677,061

This has much increased. Louisiana produced in 1858 three hundred and sixty-two thousand two hundred and ninety-six hogsheads, at sixty-nine shillings per hogshead, and value of twenty-four millions, nine hundred and ninety-eight thousand, four hundred and twenty-four dollars. A hogshead is half a ton. Total Maple sugar produced in 1859 is believed to be twenty-seven thousand tons, or sixty millions four hundred and eighty thousand pounds.

The annexed extracts from the commercial review of Messrs. DE CONINCK, Brothers, and Company, furnish some interesting particulars of the statistical position of sugar in France.

The importation of foreign sugar into that country rose in 1859 to eighty-two thousand tons against forty-five thousand tons in 1858, and sixty-five thousand tons in 1857.

From the Colonies, France received last year five thousand tons more than in 1858; while the manufacture of indigenous or beet-root sugar produced in the season 1858-9, was one hundred and thirty-two thousand tons, being twelve thousand tons in excess of the first estimates. During the last six years, the quantities received by France from her Colonies were as follows:—

113,000 tons in 1859	95,400 tons in 1856
108,000 tons in 1858	89,000 tons in 1855
92,100 tons in 1857	82,000 tons in 1854

99,500 tons in 1847.

The sources of these supplies are subjoined:—

QUANTITIES STATED IN TONS OF 1000 KILOGRAMMES.

	Guadeloupe.	Martinique.	Reunion.	Cayenne, &c.	Total.
1859	24,400	27,900	58,600	1100	113,000
1858	29,500	27,400	52,000	—	108,000
1857	18,500	22,300	51,000	300	92,100
1856	21,600	26,600	57,000	200	95,400
1855	21,000	18,500	49,900	600	89,000
1854	22,001	24,300	35,700	—	82,000

The consumption of sugar in France in 1859 is thus estimated:—

	Tons.
Sugar—Indigenous......................	120,000
〃 From French Colonies..........	95,000
〃 〃 〃	60,000
Total....................	275,000
Deduct export of refined sugar..........	52,000
Remains for consumption in France.....	223,000

The season of 1858–59 produced of indigenous sugar—

132,600 tons against 156,000 tons { 1857–58
........1856–57
........1855–56 }

It is not thought that the quantity produced in the season 1859–60 will exceed that of the preceding one, *videlicet*, one hundred and thirty-two thousand tons.

ZOLLVEREIN CUSTOMS RECEIPTS ANNUALLY FROM 1834 TO 1857, BOTH INCLUSIVE.

Years.	Total population of the States of the Zollverein.	Gross receipts in account of export, import, and transit duties.	Average sum per head of the population, derived from custom dues, *et cætera*, tax on beet-root.	
		Rix-dol.	Groschen.	Pf.
1834	23,478,120	14,815,723	18	11
1835	23,478,120	16,880,180	21	7
1836	25,150,216	18,462,873	22	0
1837	25,150,898	17,997,295	21	6
1838	25,048,970	20,419,287	23	6
1839	26,048,970	20,869,488	24	0
1840	26,048,091	21,606,191	24	11
1841	27,142,116	22,255,204	24	7
1842	27,578,730	23,653,269	25	9
1843	27,623,815	25,720,761	27	11
1844	28,498,136	26,778,300	28	2
1845	28,499,566	27,721,436	29	4
1846	28,508,436	26,569,214	28	3
1847	29,461,381	27,552,996	28	3
1848	29,460,764	22,699,299	23	6
1849	29,461,628	23,649,730	24	7
1850	29,800,063	22,948,809	23	8
1851	29,800,063	23,256,058	24	11
1852	29,800,063	24,649,721	26	6
1853	30,492,792	22,016,154	23	10
1854	32,559,173	23,157,407	24	9
1855	32,559,164	26,323,372	27	9
1856	32,721,344	26,156,450	28	0
1857	32,940,780	26,595,788	29	5

The duty is now seven and a half groschen for one hundred pounds, and brings nearly three shillings per head.

AMOUNT OF RAW BEET-ROOT USED FOR THE PRODUCTION OF SUGAR, AND AMOUNT OF DUTY RECEIVED IN THE STATES OF THE ZOLLVEREIN.

Years.	Amount of beet-root used for sugar.	Produce of the tax in rix-dol.
	Cwt.	
1842 to 1847	4,322,712	232,991
1847 to 1853	13,998,570	1,156,744
1853 to 1856	19,832,679	3,966,536
1856 to 1857	27,551,207	5,312,856
1857 to 1858	28,915,133	5,783,033

CONSUMPTION OF BEET-ROOT SUGAR IN THE STATES OF THE ZOLLVEREIN.

Years.	Consumption of colonial sugar.	Consumption of beet sugar.	Total consumption of sugar.
	Zollverein cwt.	Zollverein cwt.	Zollverein cwt.
1844 to 1846	1,278,421	264,283	1,542,704
1847 to 1849	1,154,005	646,650	1,800,655
1850 to 1852	739,958	1,219,718	1,959,676
1853 to 1855	654,386	1,487,452	2,141,838

In 1856–57 there were two hundred and thirty-three manufacturers of beet-root sugar in the Zollverein. In 1839–40, four and four-fifths pounds per head was consumed; in 1853–55 there were six and a quarter pounds consumed.

The shipments of beet-root sugar, according to BARUCHSON and Company of Douai, to Great Britain, were little more in 1858–59 than half those of the preceding season, owing to the prices in England being at several periods below those of France. They consist as follows:—

FROM 1ST NOVEMBER, 1858, TO 31ST OCTOBER, 1859.

To Liverpool	about	3218 tons.
To the Clyde	"	2240 "
To London	"	1614 "
To West of England	"	1234 "
To Hull	"	37 "
Total	"	8343 "

A good deal of this was re-exported, as it could not compete with Colonial.

PRICES CURRENT.

Low brown, equal to No. 7 to 8	Dutch standard—very scarce	21s 0d to 22s 6d
Light brown, equal to No. 10 to 10½	Dutch standard	23s 6d to 24s 0d
Grey and yellow, equal to No. 12	Dutch standard	25s 0d to 25s 6d

Per cwt., cost, freight and insurance to cover average.

In Russia the consumption has nearly doubled within a few years; but even now it is only two pounds per head.

Dr. ANGUS SMITH of Manchester kindly rendered his valuable aid during the progress of this article, and for which the Editor is indebted to him.

SULPHUR—*soufre*, French; *schwefel*, German—is one of the elements of modern chemists, and was a still more important one in the theory of the alchemists.

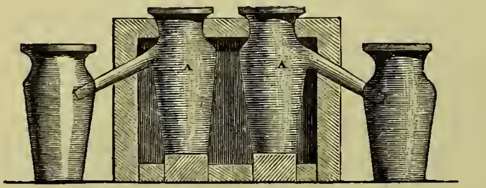
OCCURRENCE.—It is found in nature, both in a free state and in combination with metals, as sulphides and sulphates. In the free state it occurs in volcanic regions, large quantities being imported to this country from Sicily. The native sulphur occurs both amorphous and crystallized. In the latter state it usually occurs in right rhombic octohedra, although it does not assume this shape under all conditions; it crystallizes in many forms, almost as varied as the methods of procuring the body in the crystallized state. Native sulphur is far from being pure, containing a considerable quantity of adhering soil and other matter, from which it is purified by different methods dependent on the purposes to which it is to be applied. Large quantities of sulphur exist in combination with metals as sulphides; of these may be mentioned the sulphides of copper, lead, iron, and zinc; these bodies, in fact, forming the ordinary ores or minerals of these metals, from which the sulphur has to be burnt off before the metal itself can be obtained. Sulphur occurs also in nature in saline combinations as sulphates of the alkalies and earths; for instance, the sulphate of soda and potassa, which are comparatively rare, and the sulphates of baryta and lime, which occur in immense quantities.

PROPERTIES.—Sulphur is a pale yellow, solid, very brittle, becoming negatively electrical by heat or friction; it was at one time, in an earlier period of electrical history, used, when formed into globes and mounted as glass cylinders and plates are at the present day, as a source of electricity. Its specific gravity is variously stated, but most writers agree in considering it as 1·98—probably its density is dependent on the degree or stage of heat to which it has been carried while in a fused state. It is perfectly inodorous unless when rubbed, when a peculiar smell is developed. This was once supposed to arise from a hydrogen compound formed by friction; it is now ascribed rather to the production of ozone. Owing to its brittleness, as well as from conducting heat badly, it soon splits into innumerable cracks when held in the warm hand; by inclosing a stick of cast sulphur in the hand, and holding it close to the ear, this is easily detected, a continued series of very slight cracklings are heard similar to the cracklings of an electric machine when in work, only much fainter. Sulphur, though perfectly insoluble in water, is soluble in a variety of liquids, most of which are capable of dissolving a greater quantity of the body when hot than they are when cold, in consequence of which they, on cooling, deposit this excess in the shape of crystals. Oil of turpentine is capable of dissolving a considerable quantity. In fact, it has been proposed to take advantage of this property in the analysis of gunpowder; for by heating this body with turpentine in a warm state, having previously dissolved out the nitrate of potassa with water, we can dissolve out the sulphur, leaving the charcoal, which is not soluble in this menstruum, behind. Bisulphide of carbon will also dissolve a considerable quantity of sulphur, which can be again obtained in crystals by allowing the solvent to evaporate gradually. Fat oils are also capable of dissolving it. A compound called *oleum sulphuratum*, or balsam of sulphur, once figured in the Pharmacopœia of the London College, though now omitted. This was formed by dissolving sulphur in olive oil, employing a tolerably high temperature to effect the combination. Ether, petroleum, and fused paraffine, may be mentioned as solvents of sulphur.

Pure sulphur exhibits some curious phenomena in connection with heat. Although perfectly solid at the ordinary temperature, it fuses at a heat little more than that of boiling water, and at a higher heat passes through various physical changes; and finally, on raising the temperature still higher, it volatilizes completely, without leaving anything behind. The following experiment is interesting, as displaying some of the peculiarities of this body:—Procure a small saucepan, and partly fill it with fragments of sulphur; place this over a gentle fire, having first put on the lid; after a while it will fuse. This takes place at a temperature of about 228°, forming a thin brownish-yellow transparent liquid. On heating still higher a very perceptible change takes place; the sulphur, instead of remaining in the very liquid state, becomes of a thick consistence, so much so that the vessel containing it may be completely inverted without fear of loss. This occurs at a temperature of between 428° and 482°. At a still higher degree the action is reversed, the melted sulphur becomes thinner and thinner until it reaches the boiling point, when it begins to pass off as vapor. Other phenomena may be noticed by interrupting the experiment at various stages; for instance, if it be wished to obtain crystals of sulphur, it is only necessary to take the sulphur while in the first liquid stage, to pour this into a basin or other vessel with sloping sides, and there allow it to stand. In a few minutes after the top portion has solidified and formed a crust, break two holes through this crust at opposite sides of the vessel. If the basin be now inverted partially, the sulphur, which still remains in the liquid state in the interior, will run out of one hole while air rushes through the other. Let the vessel stand until cold, carefully detach the solidified mass from the containing vessel, and by means of a saw divide it into two halves. These will be found to be full of beautiful crystals of sulphur. It is possible that the first experiment may not be very successful, but a few trials will enable the operator to procure a mass of crystals, radiating into, and interlacing each other in every direction from the external crust. If the sulphur, immediately after passing, or perhaps better, while scarcely through the thick stage, be poured into water, it does not solidify and assume the ordinary yellow brittle appearance which it would do were it so treated while in the first liquid state; instead of doing so it remains in this plastic condition even when cold, bearing a stronger resemblance to caoutchouc than sulphur. In this state it is perfectly elastic, may be pulled out to a considerable length without breaking, and, in fact, does not in the remotest degree resemble sulphur. But for its color, it might be mistaken for wheat gluten, possessing the same soft elasticity as that body. It will remain in this state for some time, not resuming its ordinary aspect until after the lapse of some days.

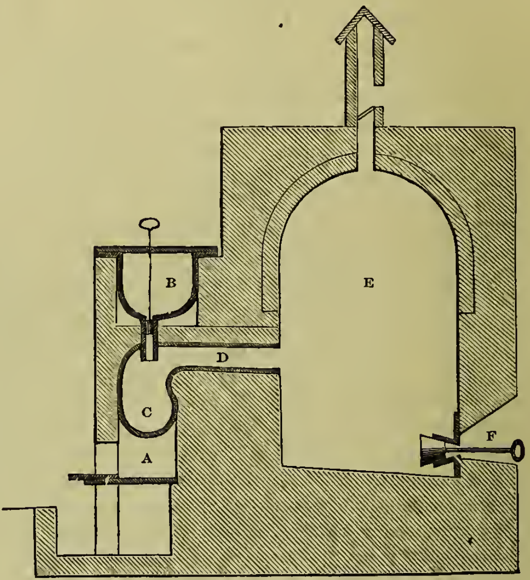
PURIFICATION.—Sulphur occurs in commerce in several states of purity, the native sulphur being the most impure. In order that it may be more fit for the several uses to which it is applied, it is partially purified from the grosser extraneous matter, such as gravel, sand, *et cetera*. This is done, according to some authors, by throwing a quantity of the crude native sulphur into a suitable iron vessel or pan, and heating this pan until fusion takes place. The sulphur when fused, of course, occupies much less space than it did in the heap, so the operator keeps filling up the pan until it is full of the fused sulphur. A high heat is not advantageous. This may be inferred from what has been said before respecting the changes which take place during the fusion of sulphur at different temperatures. For the purpose of purification the lowest heat consistent with perfect fusion is the one to be employed. The liquid sulphur is thus in its thinnest state, easily allowing the heavy particles with which it was contaminated to fall to the bottom of the pan, while any light particles rise to the top, and are skimmed off. When some time has elapsed, and the operator considers that sufficient subsidence has taken place, he proceeds to remove the upper stratum of tolerably pure sulphur, running it into moulds, from which it is removed as solid blocks of sulphur. That the method is not perfect is easily ascertained by burning a piece of ordinary commercial sulphur in a porcelain capsule. A quantity of light dust will remain, consisting to a large extent of sulphate of lime; yet, though the purification is not absolute, it produces an article pure enough to be employed for almost every purpose required in the arts. In order to procure an almost absolutely pure article, such as is necessary for medical and a variety of other purposes, distillation, or rather sublimation, must be had recourse to. Sulphur, as has been before stated, is perfectly volatile; a ready method therefore exists of separating it from all bodies which are not so. It is said that the following apparatus—Fig. 567—is employed to effect this. A A, are two earthenware or fire-clay jars, standing on a raised support of bricks. The mouths of these jars protrude slightly over the top of the furnace. This is for the purpose of readily enabling the operator to fill in the charge, and to remove the earthy residuum. A hollow tube or arm projects laterally and slightly downwards from each of the pots or retorts, which arm is thrust into another pot or vessel to receive the sublimed sulphur which condenses into it. When the subliming pot has received its charge, the lid is luted on and the furnace lighted. As they become heated, the various changes of fusion take place up to the last, when sublimation begins. The vapor then passes over into the condensing jar, and becomes solid. All the extraneous matter is left in the subliming pot, from whence it is removed prior to the introduction of another charge. This apparatus, *if actually employed*, could certainly furnish only a small quantity of sulphur. It is hardly possible to imagine a large gunpowder work using such an apparatus.

Fig. 567.



In 1815 a manufacturer named Michel, of Marseilles, devised an apparatus which, with some slight modification, is used up to the present day. The drawing—Fig. 568—represents it, and which, like the one previously described, contains a retort wherein the sulphur is converted into vapor, and a condensing chamber in which this is reconverted into solid sulphur. The apparatus, as in the drawing, consists, first, of a retort, C, beneath which is a furnace, A; this retort is filled with liquid sulphur from the reservoir, B, wherein the crude sulphur is melted by the waste heat of the furnace to facilitate its introduction to the retorts. When the retort has become sufficiently hot the sulphur begins to pass as vapor through the tube or opening, D, into the condensing chamber, E. This chamber is built entirely of brick, with a well-cemented brick floor; on its upper part a small chimney is erected; this chimney contains a sort of wooden valve or door, capable of opening outwards, to allow the expanded air to escape, and in case of explosion to allow the gases produced immediate exit. This apparatus when cold allows solid sulphur to form at once in the shape of the ordinary commercial *flowers* of sulphur; the vapors immediately on coming into contact with the cold chambers are chilled, and fall as a minutely divided solid. These flowers, as they are called, are removed before the chamber gets hot, which is the case after a few days' working, the whole of the heat which the sulphur had taken up, in order to become vapor, being given out to the walls; they thus acquire so high a temperature as to fuse sulphur, therefore it can no longer become solid in contact with them, but condenses on their surface in a liquid form, and runs to the bottom, where it collects. When the operator is satisfied that sufficient has distilled over, he proceeds to remove it; this he does by means of the plug apparatus, figured at F, which is simply an iron plug with a tolerably long shank or handle, as is shown in the drawing; by pushing this plug inwards he opens the passage for the flow of the liquid sulphur, which runs into suitable moulds, to form the *stick or roll* sulphur of commerce. The residue is raked out of the retort, which is immediately charged again by removing the plug which closes the tube or passage between the vessel, B, and the retort. An apparatus better calculated for the purpose than the above, is figured in Payen's *Precis de Chemie*, in which two retorts are attached to one condensing chamber; these retorts are cylindrical, and resemble to a certain extent ordinary gas retorts. A portion of the door which closes the outer end of the retort is movable, to enable the operator to rake out the debris left after distillation, the other end of the retort rises like a swan's neck before opening into the condensing chamber. Over these openings or orifices within the chamber hangs a damper or register in such a manner that it can, from the outside, be placed over them, thus cutting off all communication between the retort and the chamber.

Fig. 568.



A fusing vessel heated by the waste heat is attached, as in the drawing just given. This description of apparatus has the advantage, that by its means the operation can be rendered continuous. For instance, let one retort be called A, the other B; suppose retort, A, charged at a certain hour, and retort, B, charged some two hours later, it is certain that were they charged with an equal weight of raw material, the retort, A, would be ready for recharging two hours before retort, B. Supposing this to be the case, the damper or sliding plate is allowed to fall over the opening of retort, A, thus closing the passage between it and the condenser, and preventing the rushing back of any sulphur vapor. The cover is removed from the front opening, the impure residue raked out, after which it is again closed, the entrance into the condensing chamber is again opened, a charge of sulphur is run in from the fusing vessel, and the distillation again commences. During the whole of these operations retort, B, has been uninterruptedly at work; but eventually the same operations have to be performed in connection with it as have been detailed with respect to retort, A. Thus between the two a constant stream of sulphur vapor is being perpetually driven into the condensing chamber, the work going on almost without interruption, as the retorts never want charging simultaneously.

Sulphur thus produced is almost pure. It is true that the sublimed sulphur in powder—that is, the flowers of sulphur—contains a small quantity of sulphurous acid, which for some purposes it is necessary to remove by washing with water, but this is pretty nearly the only body it is contaminated with; the roll sulphur is free from sulphurous acid.

Sulphur occurs in commerce in another form intended expressly for medical use. When in this shape it is called *milk* of sulphur, and consists of sulphur in a very minute state of division. It is obtained in this state by dissolving ordinary roll sulphur bruised, or the flowers, in any caustic alkali, either soda, potassa, or lime; the latter used as being cheaper, and furnishing, as will be explained hereafter, a convenient adulterant. Sulphur does not dissolve in the alkaline solutions in the same manner that it does in turpentine, or any of the before-mentioned solvents. When boiled with an alkali a series of chemical compounds or salts are formed; in spiritous liquids it is a case of simple solution, exactly the same as dissolving sugar or salt in water, whereas in the other, a series of definite chemical phenomena takes place. If to a boiling solution of caustic potassa there is added as much sulphur as it will possibly take up, a liquid will be obtained containing sulphide of potassium, and hyposulphite of potassa, according to the following equation:—

$$3\,(KO) + 4\,S = 2\,(KS) + KO,\ S_2\,O_2.$$

In the first instance, while there is an excess of alkali, and little sulphur taken up, there is formed only sulphide of the alkaline metal and sulphite of the alkali; but this sulphite, by being boiled with an excess of sulphur, takes up another equivalent of it, being itself converted into hyposulphite. The clear liquid obtained in this way must be filtered or poured off the sediment, and excess of sulphur, and either sulphuric or hydrochloric acid added until the liquid reddens litmus paper, when the dissolved sulphur is again precipitated in an exceedingly fine state of division. This is washed, drained, and dried at a gentle heat. It remains to examine the reaction by which the sulphur is again obtained. To do this, it will be well first to notice what the effect would be of adding acid to separate solutions of the two salts which form the mixture. If a solution of sulphide of potassium be taken, and an acid be added, a copious evolution of sulphide of hydrogen ensues, and there is obtained very little, if any, precipitated sulphur. Again, if acid is poured into a solution of hyposulphite of potassa, only a little sulphur will be separated. Hyposulphurous acid consists of sulphurous acid plus one equivalent of sulphur. Now hyposulphurous acid can only exist in combination; when set free it is instantly decomposed into sulphurous acid and sulphur—$S_2\,O_2 = SO_2 + S$. This is the case on adding an acid to hyposulphites. In the first place, the alkali is detached from its combination, and this hyposulphurous acid being set free gradually resolves itself into sulphurous acid and sulphur.

It is well known that when sulphide of hydrogen and sulphurous acid are brought into contact with each other a decomposition ensues, water and sulphur being the result, as shown in the following equation:—

$$SO_2 + 2\,SH = 3\,S + 2\,HO.$$

Thus is explained the reproduction of the whole of the sulphur employed. Hyposulphurous acid and hydrosulphuric acid, or sulphide of hydrogen, are set free in the first instance; the hyposulphurous acid splits into sulphur and sulphurous acid, the latter immediately reacts upon the sulphide of hydrogen, producing together sulphur and water. This reaction is not very complete, although it is nearly so—the more correct reaction is given under *Pentathionic Acid.* In ROYLE'S *Materia Medica* it is recommended, in order to obtain milk of sulphur, to boil one part of sublimed sulphur with two parts of slaked lime and sufficient water, and to add hydrochloric acid to the clear liquid obtained.

Lime is almost invariably used by the manufacturers as a solvent, but they are guilty of substituting sulphuric acid for hydrochloric as a precipitant. By so doing, instead of forming the soluble chloride of calcium, which is easily removed by washing, they form the very insoluble sulphate of lime which, mixed with the sulphur, forms the article commonly sold by druggists as milk of sulphur, and thus what should be pure sulphur is contaminated by this worse than useless sulphate of lime, often to the extent of more than fifty per cent. In one sample obtained from a druggist, and which was stated to be pure, fifty-six per cent. of sulphate of lime was found. It is useless to argue that such a sophistication is harmless; for, although not positively poisonous, the introduction into the stomach and bowels of a quantity of this insoluble matter cannot but be productive of harm. Sulphur is used in medicine as a mild purgative, and in some skin diseases. The stores of sulphur which this country possesses, in one form or another, has not been overlooked by practical scientific men.

EXTRACTION OF SULPHUR FROM ITS ORES.—The immense quantities of sulphur stored up in the shape of sulphate of lime and baryta, as well as the sulphides of iron, zinc, lead, and copper, is almost beyond calculation. There is good reason to suppose that at some future time the sulphur combined with these metals, and which at the present time is separated from them only to be thrown into the air, will be recovered in a tangible solid form, at a price low enough to compete with foreign sulphur. The attempts to do this already have been numerous. In many parts of the country iron pyrites is plentiful, and this mineral appears to have been a favorite material with inventors. It is a mixture of bisulphide and protosulphide of iron. The second equivalent of sulphur of the bisulphide is held rather loosely, so much so that a red heat, continued for some time, will drive it off, leaving one equivalent of iron combined with one of sulphur, forming the protosulphide. Here, it would appear, a process for obtaining sulphur readily is at hand; but if it be considered that the sulphur ores of this country rarely contain more than thirty per cent. of sulphur, and that, at the most, but two-thirds of this exist as bisulphide, and that only half of this latter quantity can be expelled by heating with exclusion of the air, it will at once be apparent that the process could never be rendered remunerative. Such a method is, however, pursued in some parts of the Continent, where sulphur ores are found of a much richer kind, and in which there is also a greater proportion of bisulphide, but not exactly by the same method that sulphur is purified. The process appears to be one of slow distillation of one part of the sulphur, at the sacrifice, by combustion, of the other. It is stated—KNAPP—that not more than one-fourth of the sulphur actually contained in the pyrites is obtained. This process has formed the base for several improvements. It would appear that inventors are quite aware of the benefits that would result from the discovery of a process whereby sulphur could be separated from the pyrites on the spot, even if only the saving the expense of carriage, if nothing else, of the vast quantity of iron. The following process was invented by Mr. LEE. He first converts the sulphur in the pyrites, or other mineral, into sulphurous acid, and then proceeds to recover the sulphur from this by passing it through a quantity of coke heated to bright redness. The oxygen of the sulphurous acid combines with the incandescent carbon, forming carbonic oxide, *et cetera*, while the sulphur is left in a free state, and in vapor. It passes on to a suitable condensor, in which the bulk of it is recovered in a melted shape; that which escapes melting is received into a vaulted chamber similar to the one employed in the refining of sulphur by sublimation, and in these obtained solid in the form of flowers of sulphur.

This process, or rather the apparatus, appears to be of a very complicated character. Mr. SPENCE of Manchester, in a process patented by him a few years ago, has materially simplified it, although he works on precisely the same principle. Mr. SPENCE'S apparatus consists simply of an ordinary pyrites burner, such as is used in the manufacture of sulphuric acid, to which is attached a number of condensing vaults. He charges his burner with alternate layers of charcoal and the pyrites under treatment; having first heated the brickwork of the burner up to the proper pitch. When at work, the action is very simple—the pyrites burns with production of sulphurous acid; each atom of this gas has to traverse a bed or layer of red-hot charcoal. Now, as just before stated, carbon having a greater affinity for oxygen than sulphur has, forces this sulphurous acid to yield up its oxygen, thus setting the sulphur free. The sulphur passes on with the current of gases, and is deposited in a state of powder in the condensing chambers. This plan appears to be more feasible, and better capable of working on a large scale than the one preceding.

While speaking of precipitated sulphur, it was shown how it was possible for sulphide of hydrogen and sulphurous acid gases to react upon each other, the eventual products being water and sulphur. This reaction has been taken advantage of in a process patented by Mr. DUCLOS of Swansea. He proposes to conduct into a leaden chamber, such as is used in the production of sulphuric acid, a mixture of two volumes of sulphide of hydrogen and one volume of sulphurous acid, a quantity of steam being at the same time admitted into the chamber. This, at first sight, appears to be very workable. It is easy to see that the two gases could be regulated to each other, and a constant action go on: the sulphur in a fine state of division would be deposited on the floor of the chamber, while the excess of atmospheric air, *et cetera*, would go out through proper openings at the end of it. But it unfortunately happens that only about one-half of the sulphur actually contained in the two gases is obtained. When these two gases are brought together, water being present, the results actually are water, sulphur, and pentathionic acid—an acid of sulphur with the formula $S_5\,O_5$. Its production may be explained as follows—

$$5\,SO_2 + 5\,HS = S_5\,O_5 + HO + 5\,S\,;$$

that is to say, that five equivalents of sulphurous acid and five equivalents of sulphide of hydrogen produce, by their mutual reaction, five equivalents of water, five equivalents of sulphur, which are deposited, and one equivalent of pentathionic acid. By calculation it is thus found that by this only one-half of the sulphur would be obtained in the solid state, for in the sulphurous acid there are five equivalents of sulphur, and five more in the sulphide of hydrogen; and for these ten equivalents of sulphur one recovers only five, the rest going to form the pentathionic acid, a body for which no use in the arts has yet been found. Thus, instead of burning the pyrites, or other minerals, and endeavoring to separate the sulphur from the sulphurous acid produced, it would be more economical to convert it into sulphuric acid at once.

Mr. GOSSAGE surmounted the pentathionic acid difficulty, by causing the reaction to take place at a high temperature. His process is peculiarly applicable to the reproduction of the sulphur contained in the lime compound or alkali waste thrown away by the soda manufacturers. As is well known, the whole of the sulphur used in the manufacture of the alkali finds its way into the vat waste. Mr. GOSSAGE proceeds to decompose this vat waste by means of carbonic acid. The action of this acid causes sulphide of hydrogen to be evolved. A portion of this sulphide of hydrogen is converted by burning into sulphurous acid, which sulphurous acid is made to react, at a high temperature, on a fresh portion of sulphide of hydrogen, when water and sulphur are produced. His apparatus consists of four distinct portions—the first for the production of the requisite carbonic acid; the second for the decomposition of the alkali waste; the third is for the decomposition of the sulphide of hydrogen; and the fourth for the collection of the sulphur produced. The apparatus for the production of the carbonic acid is an ordinary lime-kiln, with some additions to render it more fit for the special purpose to which it is to be applied. It is fed with a mixture of common coke and limestone, air being admitted for the purpose of combustion in the usual manner. The apparatus is of the continuous kind. It is fed constantly at short intervals with the above materials, the quicklime produced being removed from the bottom of the kiln at stated periods. The action of this kiln is simply the decomposition of the limestone, the carbonic acid evolved, together with that furnished by the combustion of the coke, being carried to where it is needed in the next stage for the decomposition of the vat waste.

The composition of this compound may be considered definitely settled. It seems to be tacitly allowed with DUMAS that its composition is 2 $CaS + CaO$, or two equivalents of sulphide of calcium, united to one of lime; but the research of Mr. J. W. KYNASTON lately in the Editor's laboratory, has indubitably proved it to be simply a protosulphide of calcium with carbonate of lime. This substance, the composition and properties of which have been fully discussed under the article SODIUM, though insoluble in water, is capable of being decomposed by carbonic acid, especially when in a loose porous state; one equivalent of the lime compound, and three equivalents of carbonic acid producing three equivalents of carbonate of lime, and two of sulphide hydrogen, as follows:—

$$2\,CaS + 2\,HO + 2\,CO_2 = 2\,CaO\,CO_2 + 2\,HS.$$

The apparatus employed, or proposed to be employed, in the decomposition of this compound by Mr. GOSSAGE, consists of two large chambers, or rather large columns, filled with numerous perforated floorings or stages on which the alkali waste is placed; these chambers or columns are placed side by side, and so connected together, that the carbonic acid which is admitted at the bottom of one column, emerges at the top, and is conducted by a proper passage to the bottom of the adjoining column, up which it passes, as in the previous case. The material to be operated upon is laid on the perforated floors, in a loose open manner, to facilitate the passage of the carbonic acid; this ascending from the bottom of the column, penetrates through each of these separate masses, decomposing each particle with which it comes in contact. This course it pursues until it reaches the terminal point of this portion of the apparatus, at which time the carbonic acid is supposed to have been completely absorbed, and replaced by the liberated sulphide of hydrogen which has now to be decomposed. In order to this effect, the inventor has constructed a furnace of a rather peculiar character. This furnace has a closed ash-pit, or an ash-pit whose inlet can be closed or not, at pleasure, by means of a damper or register; the flue or passage for the gases leading from the waste decomposer is divided into two at this point, one part of the sulphide of hydrogen is drawn into this ash-pit, and so through the bars and fuel of the furnace, while the other portion is admitted immediately above the burning fuel; by this means a quantity of sulphurous acid is produced, which, in coming in contact with a fresh portion of sulphide of hydrogen at this high temperature, decomposes it, forming, as shown before, sulphur and water. This sulphur, of course, is in the state of vapor, mixed or diluted with a variety of other gases; it now remains to separate this valuable ingredient from the mass of inert and useless gases which accompany it. For this purpose an apparatus similar to the one last described is employed. This column is built of bricks or other suitable material, and is filled with coke; a cistern of water is placed on the top, by means of which, with the assistance of an apparatus for the spreading of the water in the form of rain over the whole area of the column, the coke is kept drenched with a stream of water. The vapors issuing from the furnace, consisting, as before stated, of sulphur vapor, mixed with other gases, is forced or drawn in at the bottom of this column, when, meeting with the cold wet coke, their temperature is almost instantly brought below the melting-point of sulphur, and this body is deposited in the solid state in the form of an impalpably fine powder, which mixes with the stream of water, and is finally carried out with the stream, forming with it a milky liquid, which falls into a proper cistern or reservoir, from which the sulphur is separated by deposition; from thence it is removed, and fused into a coherent mass, to fit it for the purposes of commerce. Between each of the different portions of the apparatus just described, the inventor places an ordinary draught or blower-fan, which rapidly removes the gaseous products from one portion, forcing them into the next. The various columns, *et cetera*, are of such dimensions as to insure a sufficiently quick passage for the products.

In theory this would appear to be perfection, inasmuch as we have here the recovery of the sulphur, which is the main object; and also the recovery of the lime, this body being left as carbonate after decomposition. As most alkali manufacturers are also manufacturers of bleaching powder, or chloroxide of calcium, this process offers an unfailing supply of lime; or if the recovered carbonate of lime just spoken of should not be found to answer for the soda decomposition a second time, that produced in the kiln could be used in the black-ash furnaces, instead of the limestone usually employed. It thus offers a considerable advantage if it should turn out to be as practically valuable as it is theoretically interesting.

Messrs. M'DOUGALL and RAWSON, in a patent, dated May 21, 1849, claim a process for the reproduction of sulphur from sulphide of hydrogen, from whatever source obtained. This they effect by passing it through a pipe, heated to a red-heat, wherein the gas is split up into its constituent elements, sulphur and hydrogen; the sulphur is collected in any convenient manner. This process does not appear eminently practical, if the experiments of CORENWINDER be correct. He states that by passing sulphur vapor and hydrogen over or through porous bodies, kept at a red-heat, he obtained sulphide of hydrogen, exactly the reverse of this process. At any rate in a laboratory M'DOUGALL'S operation answers perfectly.

Messrs. DYAR and CHISHOLME secured a patent in 1839, for the recovery or reproduction of sulphur from sulphurous acid. It consisted in submitting the gas while at a red-heat to the action of hydrogen, which latter seized upon the oxygen, forming water and liberating sulphur. Two furnaces of proper construction were erected, side by side, one adapted to the combustion of pyrites, the other constructed in such a manner that it afforded a stream of hydrogen, mixed with carbonic oxide, obtained by passing a current of steam through or among incandescent coke. The gases were brought together at a point of junction kept sufficiently hot by the combustion of the materials themselves. At this point the decomposition took place, the sulphur vapor passing on to a proper condensing apparatus.

Amongst a most numerous array of methods for procuring sulphur, or for separating it from natural combinations, perhaps one of the most theoretically ingenious is that mentioned by PARNELL as being devised by M. THAULOW. It is for producing sulphur from the natural sulphate of lime. He proposes to reduce this to the state of sulphide of calcium, which salt he then decomposes by means of carbonic acid, obtaining by this means sulphide of hydrogen and carbonate of lime. He effects the deoxidization of the sulphate of lime, or its reduction to sulphide of calcium by mixing it, in fine powder, with coal-dust, exposing this mixture to a red heat for a sufficient length of time in a retort of clay or iron; the carbon unites with the oxygen of the sulphuric acid and lime, and becomes carbonic acid, which he reserves, or immediately uses for the decomposition of a previous charge. Carbonic acid, as stated while describing Mr. GOSSAGE'S process, is able to decompose sulphide of calcium, driving off sulphide of hydrogen. Thus M. THAULOW proposes to burn sulphide of hydrogen in lieu of sulphur for the production of sulphuric acid. There are reasons for supposing that this process can never be successfully carried out. In the first place, as PARNELL observes, if the exact quantity of carbon only necessary to combine with all the oxygen present, is added, the reduction would be extended over a great length of time, and would probably never be complete; and again, were an excess of carbon to be employed, so as to hasten the decomposition, carbonic acid would not be obtained, for carbonic acid passed over red-hot carbon would part with half its oxygen, becoming carbonic oxide—CO—a gas which could not possibly be substituted for the carbonic acid in this case. By a little addition the process can be made theoretically possible; still, the probabilities are that it will never be practically worked, unless sulphur should rise in price much higher than it is likely to do.

As an instance of the manner in which old and useless, or exploded inventions again arise, one may mention the re-invention or revival of this very process by OTTO KÖHSELL, who patented it for the kingdom of Hanover in 1856. The process, as detailed by this inventor, is precisely the same in every detail as that of M. THAULOW—not the main principal only, but in every minute particular it is a perfect copy.

In 1857 Mr. GOSSAGE invented, and secured by patent—dated September 12th in that year—another process for obtaining the sulphur from the sulphide of calcium of alkali waste. In the place of hydrochloric or carbonic acid, as in his method of decomposition before mentioned, he liberates the sulphur in the form of sulphide of hydrogen, by acting upon the waste with steam at a high temperature. The following equation represents the change that ensues—

$$\underbrace{CaS}_{\text{Sulphide of calcium.}} + \underbrace{HO}_{\text{Steam.}} = \underbrace{CaO}_{\text{Lime.}} + \underbrace{HS}_{\text{Sulphide of hydrogen.}}$$

The sulphide of hydrogen so obtained he applies instead of sulphur, in the production of sulphuric acid by burning with atmospheric air, so as to form sulphurous acid gas; or he obtains the sulphur itself from the sulphide of hydrogen by causing sulphurous acid to act upon it, when mutual decomposition takes place.

When carbonic oxide gas is passed over the sulphates of the alkalies or alkaline earths in a state of ignition, the salts are reduced to sulphides with the simultaneous conversion of the carbonic oxide to carbonic acid, thus—

$$MO, SO_3 + 4\,CO = MS + 4\,CO_2.$$

Now, as Mr. GOSSAGE has shown, if steam at a high temperature be caused to act upon the sulphides of the alkaline earths, sulphide of hydrogen is liberated. If, therefore, a mixture of steam and carbonic oxide gas be passed over the ignited alkaline, or earthy sulphates, the sulphur of the sulphate will be obtained as sulphide of hydrogen, and may afterwards be obtained in the free state. This method has been lately proposed by M. JACQUEMIN, for the production of sulphur from sulphate of lime, and also for obtaining, at the same time, soda in the caustic condition from sulphate of soda.

The author appears to think that by means of this process he will revolutionize the soda manufacture, as he anticipates the recovery of the whole of the sulphur in an available form without the production of any waste whatever. Even if this process would answer on a small scale, its success on a larger one is very doubtful. Were its success an absolute and undoubted fact, and the reaction clean and exact, it would be capable of considerable extension. The sulphur from sulphate of lime might be recovered in like manner. It would only be necessary to mix it in the manner M. THAULOW proposes to do with small coal, or other carbonaceous or reducing matter; heat to bright redness in a closed retort for some hours, until it was reduced to the state of sulphide of calcium; then to pass steam over and drive off the sulphur as sulphide of hydrogen, while lime would remain behind as quicklime. This process, which is tacitly indicated by the author, should be much superior to that of M. THAULOW just mentioned; but it would appear that a like fate has awaited both processes; in fact, that they are each impracticable on a large scale, or, what is the same thing, they would not pay at present.

These are not the only methods which have been proposed for the recovery of sulphur from its various combinations; but they serve to show, to a certain extent, the industry of the various inventors who have turned their attention to the subject; and though success has not followed to the extent no doubt expected by the sanguine chemist, there is no reason for despair. It is still to be hoped that some one, more successful than his predecessors, may yet, in some fortunate moment, hit, either upon a yet latent reaction, or by some perhaps trifling variation of an already known mode of procedure, bring forward a simple and easily-worked process, that shall be all that could be desired, producing sulphur at a price sufficiently low to compete successfully with the imported article. Sulphur, in a state of combination, exists in this country in almost inexhaustible quantity. To separate this, and to produce it in a state of comparative purity, is what is wanted. When this is done, English manufacturers will be in a state of great independence. It scarcely need be added that by such a discovery the fortunate individual would be more than repaid for a life's industry.

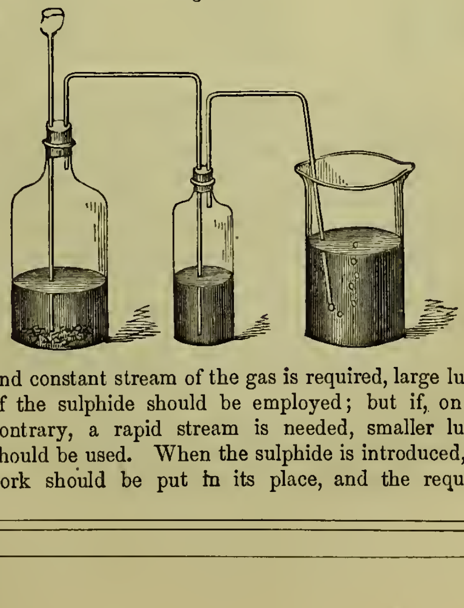
COMBINATIONS OF SULPHUR.—Sulphur enters into many combinations, both simple and complex; it combines, with a few exceptions, with all the metals, forming with them proper insoluble compounds. The sulphides of the alkaline and earthy metals are soluble in water. Some sulphides are decomposed by acids, while others again are insoluble in these liquids. Of these peculiarities chemists avail themselves largely in analysis; for, by this property of forming insoluble compounds with sulphur, they are enabled to separate into classes several groups of metals, from which again, by a series of subdividings and subclassings, they can separate individually each element. The larger groupings are made chiefly through the instrumentality of sulphide of hydrogen. This gas, when passed through a solution of metallic oxides, in many cases throws down the metal as a sulphide, the gas being decomposed. As an example: if a current of sulphide of hydrogen be passed through a solution of a salt of lead, the following reaction takes place—

$$\mathrm{PbO + HS = PbS + HO.}$$

Sulphide of lead and water are the products of this decomposition. The following metals are thrown down as sulphides by sulphide of hydrogen from an acid solution—gold, platinum, mercury, silver, lead, bismuth, and copper, black; antimony, orange; arsenic, tin, and cadmium, yellow. The following metals are converted into sulphides when sulphide of hydrogen is passed through their alkaline solutions, or a slightly alkaline solution, in which their hydrated oxides are suspended—nickel, iron, and cobalt, yellow; tin, black; manganese, flesh-colored; zinc, white. Sulphur enters into the vegetal kingdom; it is found in more or less quantity in many plants, chiefly in connection with nitrogen, with which it would appear to act in consort, at least in the organic world. In the animal kingdom it occurs pretty extensively also, and there too it is principally found in nitrogen compounds. Animal and vegetal products of the albumen and fibrin class contain it as an essential element, while its existence in the form of salt, as sulphate, *et cetera*, is still more diffused. It combines, as will be presently shown, with several proportions of oxygen, and with hydrogen in at least two proportions—the sulphide of hydrogen spoken of so repeatedly in this article when treating of the recovery of sulphur, and another body containing much more sulphur, its formula being given as HS_5. This body is produced, appearing in the form of oily drops, which subside when a solution of pentasulphide of potassium is poured into dilute hydrochloric acid; it is very unstable; the greatest care and precaution cannot preserve it longer than a few weeks, even though it be sealed hermetically in a glass tube; it simply forms a link of the chain of combinations which sulphur is capable of forming.

The simpler combination with hydrogen is a well known body; it is the result of many decompositions, natural and otherwise; it is permanently gaseous, possessing a most nauseous odor, easily recognized as being the characteristic of several mineral springs, such as those of Harrowgate, *et cetera*. It is a product of the decomposition of many organic bodies, is evolved by putrid bodies, and is the cause of the smell of rotten eggs, the albumen of which, as before stated, contains a quantity of sulphur, is undergoing decay, and gives off its sulphur, or a part of it, as sulphide of hydrogen. This gas is prepared by adding an acid to any soluble sulphide, such as those of the alkalies, or of the alkaline earths. The most convenient, and consequently the most general method, consists in adding dilute sulphuric acid to sulphide of iron, placed in a bottle, closed with a cork, perforated with two holes, one for the passage of a tube funnel, through which sulphuric acid can be poured; while through the other is passed a tube for the exit of the gas—Fig. 569. If a slow and constant stream of the gas is required, large lumps of the sulphide should be employed; but if, on the contrary, a rapid stream is needed, smaller lumps should be used. When the sulphide is introduced, the cork should be put in its place, and the requisite

Fig. 569.



quantity of dilute acid poured down the funnel; if the sulphide be good, a stream of gas bubbles will immediately begin to rise, and passing through the exit tube, can be directed through any solution, or to any required point. The decomposition which produces this gas from these materials is very simple—

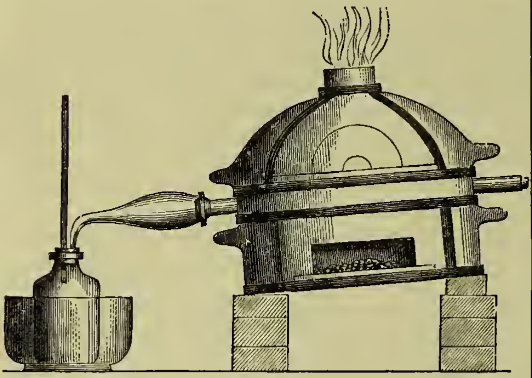
$$Fe\,S + SO_3\,HO = Fe\,O,\ SO_3 + S\text{H};$$

that is, one equivalent of sulphide of iron, one of sulphuric acid, and one of water, produce one equivalent of sulphide hydrogen, and one of protosulphate of iron.

The combination of sulphur with nitrogen alone is of scarcely any importance, and need not be dwelt upon.

Sulphur and Carbon.—Sulphur forms several combinations with carbon; the one most marked and of the greatest importance, inasmuch as it is used in the arts, is the bisulphide of carbon or sulphocarbonic acid—CS_2. It is formed by passing the vapor of sulphur over or through red-hot charcoal. This is effected by filling an iron or porcelain tube placed across a furnace—Fig. 570—with fragments of charcoal. One end of this tube is connected with a condensing apparatus—LIEBIG's tube will do—plentifully supplied with cold water. The other end of this tube must be capable of being closed tightly with a cork. When the tube is sufficiently hot the cork is removed, and small pieces of sulphur are pushed through near to the charcoal. The orifice being again closed, the sulphur is converted into vapor, and in passing through the *interstices* of the *incandescent* carbon, combines with a portion, forming the body in question, which, passing on to the condensing apparatus, collects as a liquid. After sufficient time has elapsed a fresh portion of sulphur must be introduced, the operation being continued in this manner until sufficient has been prepared. This product is by no means pure, containing more or less sulphur which has escaped combination, and from which it must be freed by distillation in a glass retort placed in a water bath.

Fig. 570.



Bisulphide of carbon has a density of 1·272. It is, as obtained above, a transparent, colorless liquid, of a strong disagreeable odor. This odor is due to a foreign body, the true smell being of a vinous or ethereal character. A considerable portion of this smell may be removed by shaking it up in a bottle with a quantity of strong sulphuric acid and bichromate of potassa. Bisulphide of carbon is a very volatile body, its boiling point being 110°. It rapidly evaporates, almost equaling sulphuric ether in this respect, diffusing its odor through the apartment. It is a very effective solvent fatty matter. Grease stains may be removed by it from paper or woven fabrics. It is only necessary to place a piece of blotting paper below the stain, and drop the bisulphide of carbon on it; it dissolves the grease, and the blotting paper receives the solution. When brushed the fabric must be exposed to the air, when the odor rapidly and perfectly disappears. Bisulphide of carbon is also a solvent of phosphorus; when a little bisulphide of carbon is warmed in a test tube and a piece of phosphorus dropped in it, it rapidly dissolves. This is a case of true solution. The phosphorus is again deposited unaltered on the evaporation of the solvent. It has been proposed to employ this solution in warfare. Shells filled with the solution were to be thrown into or on any combustible part of the enemy's premises, such as a wooden building or a ship's sails. The solvent evaporates, leaving a thin layer of phosphorus, or, in the case of a ship's sails, leaving every thread or fibre covered with a coating of phosphorus. This quickly begins to oxidize, and finally takes fire, which fire will communicate to the surrounding parts. The experiment may be performed on a small scale by wrapping a little tow round the end of a wire, and dipping this into the phosphoric solution, when, on taking it out and waving it about, the bisulphide of carbon almost instantly evaporates, and in a few seconds the tow takes fire, the phosphorus having ignited first.

Sulphur and Chlorine.—Sulphur also combines in a variety of proportions with other bodies, as well as those named. It forms combinations with phosphorus, boron, iodine, bromine, fluorine, and chlorine. One of its combinations with the latter body is used in the manufacture of caoutchouc; it is prepared by passing chlorine gas through melted sulphur, forming the dichloride of sulphur, which is found to contain also sulphur in solution. From this it must be freed by distillation, at a low temperature, and, if necessary, the rectification repeated until its boiling point is stationary at 228·2°. This chloride of sulphur has some curious properties; by means of it, a species of artificial india-rubber may be produced. To procure this body take a quantity of vegetal oil, say linseed or rape, and mix it with one-tenth its bulk of chloride of sulphur, and slightly warm the mixture; a strong reaction takes place. Hydrochloric acid is disengaged, and a mass remains, which, when washed with water, becomes white, and is as elastic as genuine caoutchouc, with precisely the same appearance. This curious body resists the action of boiling alkalies; ammonia and concentrated acids are without action on it, and it resists the solvent powers of alcohol, ether, sulphide of carbon, and oils.

Compounds of Sulphur and Oxygen.—Sulphur appears to have a great affinity for oxygen, with which it combines in many proportions, forming a series of compounds, all of which are acids. The following are known to exist at present:—

Hyposulphurous acid,	S_2O_2
Pentathionic acid,	S_5O_5
Tetrathionic acid,	S_4O_5
Trithionic acid,	S_3O_5
Sulphurous acid,	$S\ O_2$
Hyposulphuric acid,	S_2O_5
Sulphuric acid,	$S\ O_3$

Of this series two members have been already noticed —hyposulphurous acid and pentathionic acid. Hyposulphurous acid cannot be obtained in the free state, as already mentioned. When set free it splits up gradually into sulphur and sulphurous acid. It is commonly met with in the form of hyposulphite of soda, a compound employed to a considerable extent by photographers, it being a solvent of certain silver salts, which are insoluble in water, such as the chloride, iodide, and bromide. Hyposulphite of soda will also dissolve sulphate of lead, and in analysis affords a ready means of separating this salt from sulphate of baryta.

Hyposulphurous acid is comparatively stable when combined with a base. The hyposulphites of the alkalies and of the alkaline earths are those most frequently occurring. They are prepared in a variety of ways, the most common methods being either by exposing an alkaline or earthy sulphide to the air, when it absorbs oxygen, forming a quantity of hyposulphites and other salts; or by boiling a sulphite of the base with sulphur. The reaction in the latter case is very simple. Take the sulphite of soda for instance. This has the formula NaO, SO_2. Add to this one equivalent of sulphur—$NaO, SO_2 + S$; and hyposulphite of soda—NaO, S_2O_2—is produced.

The following method appears to be a favorite one for preparing the hyposulphite of soda in small quantities:—One pound of pure crystallized carbonate of soda, is dried as perfectly as possible. When powdered, this is mixed with five ounces of pure sulphur, the mixture heated in a glass or porcelain basin to the melting point of sulphur, and kept at that temperature for some time, stirring constantly in order to bring every part into contact with the air. The sulphide of sodium formed at first absorbs oxygen from the air, and is converted with feeble incandescence into hyposulphite of soda. The mass, when cold, is dissolved in water, and boiled with sulphur for some time, and the liquid evaporated to the crystallizing point. Very fine and pure crystals are obtained in this manner. If the heat be too strong, part of the sulphur is burned off, and carbonate of soda remains undecomposed. In this case a second crystallization is requisite. Hyposulphite of soda can easily be obtained by passing a current of sulphurous acid through a solution of sulphide of sodium, boiling, filtering, and evaporating to the crystallizing point.

The earthy hyposulphites, as above stated, are formed by exposing their sulphides to the air; for instance, in a solution of sulphide of calcium exposed for some time in this manner, a considerable quantity of hyposulphites form by double decomposition. The hyposulphite of soda or potassa may be formed by adding to a solution of the sulphide of calcium a solution of the carbonate of these alkalies.

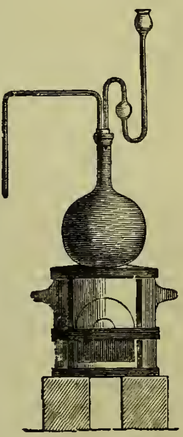
Hyposulphite of soda is used to a small extent in analysis as a reducing agent, also as a means of separating iron and alumina, dependent on the fact that hyposulphite of alumina is not stable at much above the ordinary temperature. For instance, suppose iron and alumina are both contained in a solution; to this solution is added as much hyposulphite of soda as will convert these bases into hyposulphites; this is done while cold. The solution is now heated to boiling. Hyposulphite of alumina decomposes at this temperature into sulphur, sulphurous acid, and alumina, while the iron salt being more stable remains intact. The whole is now thrown on to a filter; when the iron salt passes through, while the alumina remains on the filter; and it is washed, dried, and ignited. The iron is separated from the filtrate in the usual manner.

This reaction is used, also, to a very small extent in calico-printing. A hyposulphite of alumina is formed in the cold by adding a solution of chloride of aluminium to a solution of hyposulphite of soda. The result is a solution of chloride of sodium and hyposulphite of alumina. This is thickened in the regular manner, and printed on the fabric. The piece is then exposed to a temperature of 212° by means of steam, when the salt is decomposed, alumina being deposited on or in the cloth. This alumina so deposited dyes up with madder precisely like the alumina precipitated in the ordinary manner from the acetate.

This method does not offer any advantage over that usually followed, except in certain cases, where it is a convenient course, on account of the ordinary method being inadmissible.

The rest of these sulphur and oxygen compounds, with the exception of sulphurous and sulphuric acid, are at present useless in the arts, but are valuable in a scientific point of view.

Fig. 571.



Sulphurous acid is composed of one equivalent of sulphur and two equivalents of oxygen. It is the irritating vapor or gas given off by burning sulphur. It may be prepared in a variety of ways, according to the purpose for which it is required. Two general principles may be followed, either the addition of a sufficient quantity of oxygen to sulphur, or the abstraction of oxygen from sulphuric acid.

When sulphur, as just stated, is made to burn in oxygen gas or common air, sulphurous acid is obtained. If it is desired to pass a stream of this gas through any liquid intended to absorb it, the sulphur must be burned in a close vessel or apparatus, which has a strong aspirator attached. The **Woulf's** bottle, or other vessel, must be placed between the vessel containing the sulphur and the aspirator, or, supposing this to be inconvenient, the sulphur may be mixed with some body containing oxygen loosely combined, and this mixture heated. A body possessing these requisite qualifications is found in peroxide of manganese. To obtain a stream of sulphurous acid, it is recommended to make an intimate mixture of one part powdered sulphur, and seven or eight parts of black oxide of manganese. This mixture is placed in an iron retort, which is set on the fire. There is given off sulphurous acid, oxygen, and sulphur vapor, the matter in the retort being probably sulphide and sesquioxide of manganese. This method, not giving a very pure product, is not well adapted for many purposes. The method generally adopted is that of robbing sulphuric acid of one equivalent of oxygen by any convenient body. A mixture of strong oil of vitriol and charcoal heated in a flask, which has a conducting tube—Fig. 571—attached, serves very well, if absolutely pure gas be not needed. The gas given off by the mixture is a compound of SO_2 and CO_2. The following being the reaction—

$$2\,SO_3 + C = 2\,SO_2 + CO_2.$$

But sulphurous acid as nearly pure as possible, in fact quite pure, if made to traverse a little water to take up any sulphuric acid, may be obtained by heating sulphuric acid with one-third its weight of copper, in the shape of turnings or clippings. One atom of copper takes up one atom of oxygen from one atom of sulphuric acid, and becomes oxide of copper, which itself immediately combines with another equivalent of sulphuric acid, forming sulphate of copper—

$$2\,SO_3 + Cu = CuO\,SO_3 + SO_2.$$

Mercury may be substituted, but with no advantage—a like reaction takes place. The sulphurous acid so obtained is permanently gaseous at the ordinary atmospheric pressure, but is capable of assuming the liquid form, like carbonic acid, sulphide of hydrogen, and sundry other gases, at an increased pressure with a very low temperature. **Faraday** employs a pressure of from three to five atmospheres; **Wach** places in a long glass tube, sealed at both ends and bent in the middle, a mixture of anhydrous sulphuric acid and sulphur. This is heated, while the opposite end is kept immersed in a freezing mixture. Sulphurous acid is formed under strong pressure, and condensed in the cooled end of the tube. In order to obtain it pure, it must be run to the other end of the tube, and again distilled to free it from sulphuric acid. Sulphurous acid in the liquid state is only of scientific interest; it is like many other rare chemical preparations, which are only made at a cost of great labor, and when made, can only be preserved conveniently for a very short time. As a liquid its boiling temperature is 14°.

As far as all the useful properties of sulphurous acid are concerned, they may be studied from its solution in water, this liquid taking up, at mean temperature, thirty-three times its bulk of the gas.

Sulphurous acid solution is obtained by passing a stream of the gas through cold water, employing for the generation any of the methods just given. A series of **Woulf's** bottles, or other convenient apparatus, may be employed for the condensation. The contents of the first bottle should always be rejected, as it will contain a considerable quantity of sulphuric acid, carried over both mechanically and in a state of vapor; the other will be a nearly pure solution of sulphurous acid.

Sulphurous acid is capable of forming a crystalline hydrate with water. It is procured by exposing sulphurous acid vapor with water, in a tube or other apparatus, to a low temperature, by placing this tube in a freezing mixture. Solid sulphurous acid may be procured by rapidly evaporating the liquid acid—it forms white flakes. It is heavier than the liquid, and freezes at *minus* 110°. It is composed of—

$$\left.\begin{array}{l}\text{Sulphur vapor,...1}\\ \text{Oxygen gas,....6}\end{array}\right\}\text{forming 6 vol. of spec. grav. 2·2113.}$$

Sulphurous acid is a powerful deoxidizer, instantly decoloring acid solutions of the manganates and chromates—in the latter case reducing them to the state of green sesquioxide of chromium. For analyzing the commercial sulphites, it is only necessary to weigh out a stated quantity of the sulphite or hyposulphite to be examined, dissolve it in water, make it acid with hydrochloric acid, and then to note the number of measures of a normal solution of bichromate of potassa required to be added to convert the sulphurous into sulphuric acid, and data are obtained from which the amount of sulphurous acid contained in the sample may be easily calculated. This reducing property of sulphurous acid has been turned to advantage by **Bunsen**, in the indirect analysis of various bodies—for instance, in the valuation of manganese. He places the manganese in a flask, treats it with hydrochloric acid, passes the evolved chlorine into a solution of iodide of potassium; each atom of chlorine sets free an atom of iodine. When the operation is over, he disconnects the vessel containing this iodine, and adds from a burette a normal solution of sulphurous acid until the precipitated iodine has disappeared. Each equivalent of iodine converts an equivalent of sulphurous into sulphuric acid, as follows—

$$SO_2 + I + HO = SO_3 + IH.$$

Thus, tracing the reaction back, one equivalent of sulphurous acid represents one equivalent of binoxide of manganese—this principle is applied in a variety of ways. The deoxidizing power of sulphurous acid is taken advantage of by the chemist in the estimation of arsenic. When arsenic exists as arsenic acid, it is very slowly thrown down by sulphide of hydrogen; whereas arsenious acid is easily precipitated. Sulphurous acid possesses the power of abstracting part of the oxygen from arsenic acid, reducing it to arsenious; so that, if a stream of sulphurous acid be passed through the arseniate to be analyzed, after making it acid with hydrochloric acid, it is converted into arsenious acid, which facilitates its precipitation when one comes to employ sulphide of hydrogen.

Sulphurous acid, passed through a dilute solution of yellow sesquichloride of iron, quickly reduces it to a protosalt—

$$Fe_2\,Cl_3 + SO_2 + HO = 2\,Fe\,Cl + SO_3 + H\,Cl.$$

Sulphurous acid reduces salts of gold, throwing down the gold in the metallic state. It is capable of taking up the second equivalent of oxygen from almost every metallic binoxide.

Sulphurous acid, in the shape of sulphite of soda, has been an article of commerce for some time, under the half-fanciful and half-true appellation of antichlor. It has derived its name from the use to which it is applied, being used to correct the evil effects of an overdose of chlorine. In the bleaching of paper pulp, if any excess of chlorine or hypochlorite has been used, the sulphite, on being added, neutralizes it. If, for the sake of illustration, we imagine chlorine to have been used, then—

$$Cl + SO_2\,NaO + HO = Cl\,H + SO_3\,NaO.$$

This hydrochloric acid can be taken up by any alkali, or will itself decompose a fresh portion of the sulphite, driving off sulphurous acid.

Sulphites are used by some in the manufacture of beet sugar. PROUST recommended them and a sulphurous acid solution as being antiferments, and having also other advantages. The following method of procuring it in large quantities was proposed by CALVERT, in a lecture lately delivered before the Society of Arts. He constructs a sulphur oven, such as is used in the manufacture of sulphuric acid. Within this oven the sulphur is burned, producing sulphurous acid. An earthenware tube, immersed in water, leads from this burner or oven to a tall wooden column filled with pumice-stone, or other suitable porous body. A cistern of water is placed on the top of this column, to which cistern a tap or valve is attached, by means of which a shower of water can be sprinkled on the pumice-stone, keeping it in a moist or wet state. The mixture of gases issuing from the burner, consisting of sulphurous acid, atmospheric air, and residual nitrogen, pass along the conducting tube, enter the column near the bottom, and pass up its whole length, thus meeting with the descending water; the sulphurous acid is absorbed, and a constant stream of the solution issues into a cistern placed at the bottom for its reception, while the residual gases pass out into the atmosphere.

Some brewers employ a solution of sulphurous acid to rinse out beer barrels after washing, as it possesses the property of arresting the acetic fermentation.

Sulphurous acid, when present in a free state in small amounts, is easily detected by its suffocating odor. It does not, like sulphuric acid, give any reaction with a salt of baryta, except when combined with a base. This is on account of the sulphite of baryta—unlike the sulphate—being soluble in free acid. When sulphuric acid is added to a salt of baryta, sulphate of baryta is formed, and the acid with which the baryta was previously combined is set free. But this acid can exert little or no action on the sulphate of baryta. Now, on adding sulphurous acid to a salt of baryta, the sulphite of baryta would dissolve in the acid set free, and which was previously combined with the baryta. But in the case of a salt having sulphurous acid in its composition, this does not occur. No acid is set free to exert a solvent action. For instance, if to a solution of chloride of barium is added a solution of sulphite of soda, a white precipitate of sulphite of baryta will be produced—

$$NaO\,SO_2 + Ba\,Cl = BaO\,SO_2 + Na\,Cl.$$

Supposing it to have been doubtful whether the salt employed was a sulphite or a sulphate, one can now determine the point by the addition of an acid, say hydrochloric acid. Sulphite of baryta being soluble in this acid, the precipitate will disappear if the salt was a sulphite; if the precipitate is persistent, a sulphate is indicated. Of course, both may be present.

An old specimen of sulphite is sure to contain a quantity of sulphate, formed by oxidation, even though pure originally. To determine absolutely the presence or absence of sulphurous acid in a body, it is only necessary to dissolve it in hydrochloric acid, if solid, or if a liquid, make it acid to the same extent, and add a few scraps of zinc, such as is used in the production of hydrogen gas. If the body under examination contain sulphurous acid, the hydrogen going off will be accompanied by sulphuretted hydrogen, which may be detected by the smell, or by its blackening paper dipped in a solution of a lead salt. This test will discover very minute quantities of sulphurous acid. Such is its delicacy that sulphurous acid may be detected in much of the commercial hydrochloric acid; it arises from the action of the strong sulphuric acid on the iron decomposing vessel employed. The reaction may be explained as follows, leaving out the hydrochloric acid:—

$$SO_2 + HO + 3\,Za = 3\,ZnO + SH.$$

One method of estimating sulphurous acid has been given, but the ordinary method is to convert it into sulphuric acid, and then proceed in the manner followed in the estimation of that acid. This may be effected by several oxidizing bodies. It is sometimes recommended to employ nitric acid, but there is a chance of error by doing so, inasmuch as a quantity of the sulphurous acid may escape whilst heating it. Perhaps the best method is to pass through the sulphurous acid or the sulphite to be analyzed a current of chlorine until the liquid smells of the latter gas, placing it on a sand bath until all smell has disappeared, then precipitate with a salt of baryta, collect, wash, ignite, *et cetera*, exactly as indicated under the head SULPHURIC ACID.

Sulphurous acid forms, with bases, a series of salts called sulphites, one of which has been already mentioned, the sulphite of soda. These sulphites have been shown by the Editor to bear a strong resemblance to carbonates, being also isomorphous with the latter salts. The following list proves the analogy:—

Sulphites.	Carbonates.
$KO, SO_2 + 2\,HO$	$KO, CO_2 + 2\,HO$
$KO, SO_2 + HO, SO_2$	$KO, CO_2 + HO, CO_2$
$NaO, SO_2 + 10\,HO$	$NaO, CO_2 + 10\,HO$
$NaO, SO_2 + HO, SO_2$	$NaO, CO_2 + HO, CO_2$
$NaO, SO_2 + HO, SO_2 + 8\,HO,$	$NaO, CO_2 + HO, CO_2 + 8\,HO$
BaO, SO_2	BaO, CO_2
SrO, SO_2	SrO, CO_2
$MgO, SO_2 + 3\,HO$	$MgO, CO_2 + 3\,HO$
$MnO, SO_2 + 2\,HO$	$MnO, CO_2 + 2\,HO$
PbO, SO_2	PbO, CO_2
AgO, SO_2	AgO, CO_2

Sulphite of soda is the only salt—with the exception of a mixed sulphite of lime and magnesia—which is manufactured on a large scale. Sulphite of soda is made by passing a stream of sulphurous acid gas through a solution of carbonate of soda; the carbonic acid is displaced, and sulphite of soda is formed. On the large scale, the same method as is pursued in the manufacture of bicarbonate may be followed for the production of the sulphite. A chamber or suitable large vessel is so constructed with appliances that a stream of sulphurous acid from burning sulphur may be drawn through. This chamber or vessel is filled with crystals of carbonate of soda; the stream of sulphurous acid in its passage through the interstices of the mass is taken up, carbonic acid being evolved. The passage of the gas must be continued until a sample taken out of the chamber, on being dissolved, has an acid reaction with litmus paper. The mass of what was originally carbonate of soda has now become a mixture of sulphite and bisulphite of soda. This is now dissolved in water, and brought to the boiling point; a solution of carbonate of soda must now be added, until the last addition causes no evolution of carbonic acid; the whole is now brought to the state of neutral sulphite; and after standing to deposit any mechanical impurities may be run off into a suitable vessel to crystallize.

The sulphites of potassa and ammonia may be prepared in a similar manner to that of soda, by passing sulphurous acid through a solution of the alkalies or their carbonates.

The sulphites of the alkaline earths are prepared either by exposing the moistened, or better, the hydrated oxides, to gaseous sulphurous acid, when this gas is absorbed; or the oxides or carbonates may be suspended in water, and a stream of sulphurous acid passed through; or they may be produced by double decomposition from a soluble alkaline sulphite, and a chloride of the earthy metal. These sulphites are all more or less nearly insoluble in water and alcohol, but are rendered more soluble by an excess of sulphurous acid, in this respect resembling the carbonates. The only practical purpose to which any of these earthy sulphites have been applied, is as disinfectants. For this purpose, a mixture of the sulphites of lime and magnesia is used. Mr. M'Dougall seems to have a method of producing sulphites much more readily than any other maker.

The sulphites of the metals proper, such as iron, zinc, lead, bismuth, *et cetera*, are produced by analogous processes; they, like the earthy sulphites, are more soluble in a solution of sulphurous acid than in pure water.

SULPHURIC ACID—*acid sulphurique*, French; *schwefelsäure*, German—is the most stable and the best known oxide of sulphur. It appears to have been known from very early times. Brande, in speaking of it, says that the honor of its discovery is due to Basil Valentine. He frequently mentions it and its mode of preparation; and Paracelsus, and the authors who immediately followed, talk of it as well known and in common use, though it is probable that it bore a high price, and was but scantily supplied by a few awkward and unintelligent operators. But Kopp shows evidently that Vincentius de Beauvais had an idea of the substance obtained by distilling alum. Boyle first recognized in it a relation to sulphur. Mayow pointed it out with great clearness, but he was far before his time in penetration. Stahl believed sulphur to consist of sulphuric acid and phlogiston, a theory in conformity with the rest of his system. Lavoisier showed the formation of acid by sulphur taking up oxygen, but it had been made by burning sulphur in the air, at least since the time of Lemery and Dr. Ward. Sulphuric acid exists, as free acid, in two states, liquid and solid—the liquid being a combination of dry acid and water. The right of the dry body to be called sulphuric acid is doubted, as it exhibits no acid characters until combined or mixed with water. The character of the acid is sufficiently shown in the reactions of the monohydrated sulphuric acid—SO_3 HO—or the purified oil of vitriol. This body is a heavy fluid, above three-fourths heavier than water. It flows when poured from one vessel to another, in a heavy, smooth, *oily* stream. This oily appearance has, doubtless, given it its name; and although this appellation, oil of vitriol, has been much ridiculed, it cannot be disputed that it is very expressive, and serves well to distinguish the strong vitriol from the dilute acid, which bubbles like water when poured. Oil of vitriol has a strong attraction for water, so much so that a bottle containing it, if left open, rapidly attracts moisture from the air, becoming itself much weaker. This property is often taken advantage of in analytical operations. When a stream of dry gas is needed, it is simply requisite to pass it through strong sulphuric acid, or through a wide tube filled with fragments of coke or pumice-stone saturated with the acid. This is a very effectual mode of drying a gas. It is not applicable to certain gases, between which and the sulphuric acid a reaction might take place. In the simple and elegant apparatus, devised by Fresenius and Will, for the estimation of carbonic acid, sulphuric acid is employed for the purpose of desiccating the carbonic acid before it emerges from the apparatus. It has been stated that sulphuric acid possesses the property of absorbing carbonic acid, and that consequently the operations in which its drying property has been taken advantage of cannot be correct. This, again, has been refuted; and, inasmuch as most chemists are in the habit of using this apparatus, it would appear to be tacitly allowed that if any error from this source does exist, it is so small as to be of no consequence.

This attraction of sulphuric acid for water also brings about some curious decompositions with organic bodies. For instance, if any of that class of bodies, such as sugar, starch, *et cetera*, which contain carbon, hydrogen, and oxygen, in such proportions that, for the sake of simplicity, they may be considered as being composed of carbon and water, be mixed with strong sulphuric acid, and heated, a black mass will be obtained; and it this mass be thoroughly washed with water, so as to remove every trace of sulphuric acid, it will be found to be pure carbon, the whole of the elements of water having been removed. So effectual is the process, that the principle has been proposed as a method of obtaining peat charcoal without the ordinary charring process. This charcoal is then washed and dried. To this same property is due the occasional brown color of commercial vitriol. If particles of organic matter fall into it, a portion of their hydrogen and oxygen is abstracted, forming a humus-like body, which, dissolving in the vitriol, colors it. This attraction for water seems to be the principle by which it acts upon the skin, and animal and vegetal matter generally. The density of this monohydrated acid is 1·850, and it boils at a temperature of 620°. Its boiling point diminishes with its density. The strong acid is perfectly volatile, and thus capable of being distilled. It freezes at a temperature of 29°, yielding often six-sided prisms of a tabular form.

This acid has the power of supplanting or displacing almost every other acid known, so great is its affinity for bases. It produces great heat when mixed with water, the compound becoming denser than the mean of the two liquids. If equal volumes of strong sulphuric acid and water be mixed, and then allowed to cool, it will be found that the resulting liquid will not make up the original two volumes; it now occupies less space, contraction having taken place. During this contraction a portion of the latent heat of the water has been given off. PARKES made a series of experiments on this matter, the results of which are given in the following table:—

HEAT PRODUCED BY THE ADMIXTURE OF SULPHURIC ACID WITH WATER, TEN POUNDS OF SULPHURIC ACID BEING USED IN EACH EXPERIMENT.

Sulphuric acid in pounds.	Temperature of the mixture in degrees of Fahrenheit.
1	78°
2	100
3	110
4	128
5	138
6	144
7	156
8	168
9	186
10	204
11	214
12	222
13	229
14	23[illegible]
15	241
16	246
17	250
18	253
19	256
20	258
25	266
30	264
35	254
40	248

But FAVRE and SILBERMANN have lately examined the question more thoroughly, and shown that the following amount of heat is given out:—

HEAT EVOLVED BY MIXING SO_3 HO WITH WATER.

Atom of water.	Heat units.	Differences.
With the first ⅛	94·0	0·6
second ⅛	88·0	
With the first ¼	18·8	1·6
second ¼	17·2	
With the first ½	36·7	8·4
second ½	28·3	
Atoms of water.		
1	64·7	
2	94·6	29·9
3	111·9	17·3
4	122·2	10·3
5	130·7	8·5
6	136·2	5·5
7	141·8	4·4
8	145·1	3·3
9	148·8	3·4
10	148·4	0·0
20	148·6	0·0

When four of the monohydrate are mixed with one of water by weight the temperature rises to 300°.

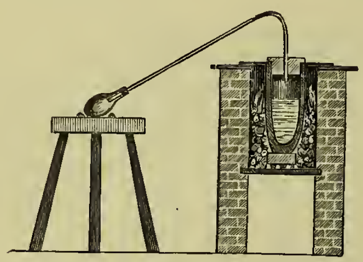
GRAHAM gives the following list of the hydrates of sulphuric acid—

Nordhausen sulphuric acid, = HO, 2 SO_3
Sulphuric acid, specific gravity, 1·850, = HO, SO_3
" " 1·78, = HO, SO_3 + HO
" " 1·632, = HO, SO_3 + 2 HO

The third hydrate in the above list corresponds nearly to the commercial brown oil of vitriol, the density of this latter being 1·758. It is formed by heating a dilute acid to 400°. Its properties are almost identical with those of the monohydrate. It has the property of solidifying at the temperature of melting ice, or a little above this point. It is no uncommon circumstance for a sulphuric acid manufacturer to find a carboy of brown vitriol converted almost into a mass of crystals, if exposed to the cold in frosty weather. These crystals are the well-defined hydrate in question. This crystallization has been proposed as a method of obtaining pure sulphuric acid, as will be seen hereafter. Little seems to be known of the lower hydrate. It is formed by heating a dilute acid at 212°. This amount of acid and water causes the greatest condensation of volume.

Neither dry nor fuming acid can be obtained by the ordinary mode of concentration, it being impossible to drive off the last equivalent of water. Dry acid may be obtained by distilling the Nordhausen acid —HO, 2 SO_3. But Nordhausen acid is not now a common commercial product; it is often necessary for the operator to make his own. This may be done either by distilling the protosulphate of iron or the sesquisulphate, artificially prepared; bisulphate of potassa or soda may be also used. This latter salt is the cheapest, and perhaps the most convenient. It may be procured by heating one equivalent of common salt in a crucible with two equivalents of sulphuric acid, taking care to operate under a chimney, or in some situation where the hydrochloric acid fumes will be carried away quickly. When gas has ceased to be evolved from the mixture, the residue must be heated to a low red-heat, in order to drive off as much water as possible. The fused salt must be removed from the crucible and allowed to cool. This may be done by pouring it out into an iron dish, or other convenient vessel. When cold, it must be broken up, when it is ready for the next operation. Or, instead of this, the bisulphate of soda or potassa left in the retorts, when procuring nitric acid, may be preserved for the same purpose. Porcelain retorts being very expensive, it is well to substitute, if possible, some cheaper piece of apparatus. For this purpose an ordinary brassfounder's crucible may be employed; a lid may be formed out of a piece of ordinary fire-tile—this lid has a hole cut through, into which is inserted a piece of glass tube to carry off the vapor. The arrangement is shown in Fig. 571. To commence, a piece of brick is first laid on the bars of the ordinary laboratory furnace; on this the crucible is placed; this is filled with the broken pieces of bisulphate; the lid is luted on with clay, and the tube luted into the lid. A fire is lighted around the crucible, and this is gradually increased in power, until at length distillation commences. Weak acid at first comes over—this is emptied out of the receiving flask; eventually the retort or crucible begins to attain a good red-heat; drops of strong acid fall, and hiss as they touch the weaker acid in the flask. The flask is now finally emptied of its contents, and replaced, the acid which now comes over being fuming acid, white vapors pour through the glass tube at a rapid pace, a portion condensing there, and a portion in the flask. The flask should be a thin one, and is all the better for being placed in a basin of cold water. After a time vapors cease to appear, and the operation is at an end. The glass tube should now be carefully taken away, as also the lid of the crucible, and the fused or softened mass, forming the contents of the latter, should be removed by means of an iron scoop. This done, the crucible should be allowed to cool slowly; when cold enough, it may be filled again, and the foregoing operation repeated. With care, a crucible will last three or four operations. The neutral sulphate may be reconverted into bisulphate, to be again employed.

Fig. 571.

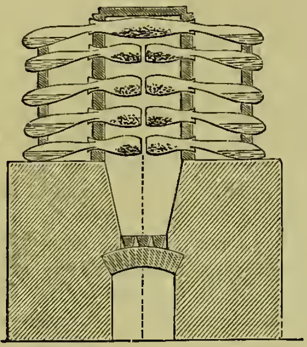


The fuming acid so obtained gives off white vapors. These white fumes are dry acid—SO_3—vapor, combining with the moisture of the atmosphere. It makes a hissing noise when poured into water, very like the noise made when red-hot iron is plunged into a liquid. This acid is employed in gas analysis, on account of its possessing the power of absorbing certain hydrocarbons. For this purpose a piece of coke is wetted with the fuming acid and passed into the gas to be analyzed, standing in a graduated tube over mercury. To obtain the dry acid it is necessary to submit the fuming acid to distillation at a gentle heat. For this purpose a glass retort is partially filled with the fuming acid, the neck of the retort is inserted into a flask, placed in cold water, a gentle heat is applied to the retort, when the dry acid begins to come over. It condenses in solid fibres like asbestos, which are tenacious, and may be moulded by the fingers like wax. Its density at 68° is 1·970; at 77° it assumes the liquid state; and a little above that temperature it enters into ebullition. If a little of this *anhydrous* acid be placed on a slip of *dry* litmus paper no reddening results—coloration not taking place until moisture has been absorbed.

Manufacture of Sulphuric Acid.—The principle involved in the mode of working adopted by Dr. ROEBUCK, who may be considered the first inventor or improver, still continues in vitriol manufactories; in fact, from that time may be dated the actual rise of the sulphuric acid manufacture.

The earlier process, and, according to many authorities, the one still followed in a few places where natural advantages render it profitable, is one already alluded to, and which consists in distilling or driving off by intense heat the sulphuric acid from protosulphate of iron. This salt is dried and placed in fireproof retorts, which are built in suitable furnaces. Proper receivers are connected with them. These retorts are charged, and heat applied, until they become sufficiently hot. The sulphuric acid is driven off and condenses in the receivers, while oxide of iron is left in the retort. The following description, extracted from KNAPP'S excellent work, will give a good idea of the process as followed at Radnitz:—The material operated upon is the mother liquor from the manufacture of alum. This contains a large quantity of protosulphate of iron. These mother liquors are first evaporated to a dry state, and then roasted at a gentle heat. During this latter roasting a considerable quantity of oxygen is absorbed, the protosulphate passing partially into basic persulphate of iron. These operations are conducted on the spot where the alum liquors are to be had. This roasted product, which is called *vitriolstein*, is sent to Radnitz for conversion into fuming oil of vitriol. This process consists in the dry distillation of the vitriolstein. The pots in which the distillation is effected are constructed of refractory stoneware, and after being baked in a kiln upon the premises, are about nine inches long, two and a half inches in diameter at the bottom, four and a quarter at the middle, and three inches at the mouth; they are about four-tenths of an inch thick in the sides. Before being used they are covered with a lute, or luting material, which is easily fritted by the action of the fire. The receivers are of much the same shape, but are longer and narrower at the mouth. The upper row in the furnace is occupied by a single range of pots twenty-eight inches in length. The gallery furnace for the reception of the pots is rectangular in section, and is composed of two parts essentially distinct. The lower part is built of massive masonry, enclosing the ash-pit and the grate, which extends the whole length under the range of pots; the upper part consists of two vertical walls of perforated brickwork, which form the sides of the furnace and support the pots. This latter portion demands frequent repair. Fig. 572 represents a front vertical section. It incloses four tiers of the smaller sized pots, arranged with their bottoms in contact, and an upper tier of long pots, which extend from one side of the furnace to the other, and are open at both ends. The whole, therefore, contains two hundred and eighty-eight pots—thirty-two large, and two hundred and fifty-six small. The long sides of the furnace are divided into squares by vertical and horizontal bricks of the same dimensions, and four pots are placed in each square, separated from each other by small bricks, the interstices being luted with refractory clay. The arch of the furnace is constructed of flat bricks, simply placed alongside each other, and cut sloping at their extremities, to allow the flame to pass. A small chimney is sometimes built to the furnace, but it is more frequently without. The pots are charged with the vitriolstein, previously broken up with a hammer, by means of a semicylindrical spoon, each pot receiving two spoonfuls. The coal for the first charge is then ignited below the grate, and is thrown upon the grate at the expiration of about an hour or an hour and a half; the fire being carefully regulated by opening or shutting the doors. At the end of four hours the lower tier of pots is brought to a dark-red heat. The receivers are successively introduced into the pots and luted, those of the second layer resting immediately upon the first, and a wooden support being introduced between the second, third, and so on. The receivers are slightly inclined, and a small quantity of water is placed in each. This is sufficient to receive the acid from four successive distillations, after which it is in the state of concentration required in commerce. The fire is gradually increased, and after from thirty to thirty-six hours no more acid is evolved from the upper tier of pots, and the distillation is finished. The whole is then allowed to cool for twelve hours, and the receivers being removed the colcothar is taken from the pots. This contains about six and a half per cent. sulphate of lime, and amounts to about thirty or thirty-five per cent. of the vitriolstein employed.

Fig. 572.



The pots are now examined by the sound which they emit when struck. The broken ones are removed, and being replaced by fresh pots, the distillation is recommenced.

Each operation lasts about forty-eight hours, and three are completed in a week. From forty-seven to fifty per cent. of the vitriolstein is obtained in fuming sulphuric acid; five parts of coal are consumed for one part of vitriolstein distilled. About thirty pots and three receivers are replaced after each distillation, which is equivalent to 10·42 and 1·04 per cent. respectively.

Although such a mode of manufacture may be capable of being followed in some localities, yet it is far from possessing the general adaptibility of the ordinary process. From the above description there appears to be little loss, except from accidental leakage or the breaking of a pot; but as the process is described by many, or in fact the greater proportion of writers, simply dry protosulphate of iron is employed—$FeO\ SO^3$—not as in the method just described, sesquisulphate—$Fe_2\ O_3\ 3\ SO_3$—or rather a basic persulphate. The employment of one or the other must make a considerable difference in the amount of product obtained, for if any protosulphate of iron be employed, only one half of the sulphuric acid contained in it will be obtained as *sulphuric acid*, the rest passing off as sulphurous acid. The following is the reaction:—

$$2\,(FeO\ SO_3) = Fe_2\,O_3 + SO_3 + SO_2.$$

Two equivalents of protosulphate of iron are decomposed into one equivalent of sesquioxide, one of sulphuric acid, and one of sulphurous acid; one of the equivalents of sulphuric acid has parted with one of its equivalents of oxygen, in order that the two equivalents of protoxide of iron might become sesquioxide. This equivalent of sulphurous acid is said to escape through the joints of the apparatus; if so, and there does not appear to be any doubt of this being the fact, inasmuch as no other provision appears to have been made for its exit, one may naturally conclude that sulphuric acid vapor must escape at the same time.

Such was the method pursued for procuring sulphuric acid for some centuries. The next process—a modification of which remains in use to this day—consisted in converting sulphur by stages of oxidation into sulphuric acid. This differs materially from the process before described, in which acid already formed was simply separated from a combination; in the present case the operation commences with the prime element. The first step in this direction appears to have been the formation of sulphuric acid in small quantities by the combustion of sulphur in glass globes, moistened on the interior surface with water. It is true that under these circumstances a small quantity of sulphuric acid would be formed, but the amount would be very minute indeed; in fact, the combustion of sulphur in pure oxygen gives rise to little more than a trace. But a grand step was made in the right direction by the introduction of nitre in the manufacture. The use of sulphur and nitre together was said to have begun with LEFEVRE and LEMERY. Dr. WARD had the monopoly of it long in this country, and best knew how to manage the process. Instead of sulphur *per se*, a mixture of sulphur and nitre was made, and set fire to in or under a bell glass; by this proceeding a much greater quantity of sulphuric acid was obtained. It can easily be imagined, that even the most successful experiment could furnish only a small quantity of acid, on account of the very limited size of the apparatus. This must strike an observer when he contrasts in his own mind the largest jar or globe that could be blown, even now, with one of the vitriol chambers of the present time. But this difficulty of limited dimensions was surmounted by a Dr. ROEBUCK of Birmingham, who was the first to introduce leaden chambers, which he did as a substitute for the comparatively small globes; and as he was able to make them of any required size, a great relief must have been given to the manufacture. The manner of working was still precisely similar to that with the globe. The chamber had an entrance-door, which could be luted tight; this was opened, and a charge, consisting of a mixture as before of sulphur and nitre, was put on a proper stand placed to receive it in the chamber. According to some authors this was a sort of carriage, which could be pulled towards the door to receive the charge, and then after ignition pushed towards the centre of the chamber; but it is difficult to conceive that this is true, as it would not be easy to find material of which to construct the wheels and other parts of such a machine, when it is considered that the floor of the chamber was covered with acid to the depth of several inches. It is certain that the proper charge was placed on a stand in the interior of the chamber; this was ignited, and the door was then properly fastened and luted. After a certain time had elapsed the door was again opened, and the residual gas or gases allowed to escape. This was repeated again and again, until the water with which the floor of the chamber was covered had absorbed sufficient of the acid, when it was run off and concentrated. Authors speak of a collapse of the sides of the chamber occurring, owing to the partial vacuum produced by the absorption of the oxygen of the contained air. But it can be scarcely believed that this accident could have occurred often, since it is hardly conceivable that practitioners of the chemical art at that time could have been ignorant of the fact that a very simple arrangement of a water-valve opening inwards would have remedied this.

This process, then, was the one followed by Dr. Roebuck, and such in principle it remains down to the present day; and had it possessed the advantage of a later invention, *videlicet*, the introduction of steam, it would no doubt have given an excellent result. Supposing there had been in the chamber twenty-four parts by weight of oxygen for every sixteen parts of sulphur introduced, watery vapor being also present in sufficient quantity, every particle of sulphur must have been converted into sulphuric acid, if sufficient time were allowed to elapse before the opening of the chamber door.

Having followed the manufacture to this point, one must now pass on to another step, from the intermittent to the continuous process, as practised at present. It is easy to see that had Dr. Roebuck burned his sulphur in a properly constructed apparatus, and introduced the resulting sulphurous acid into his chamber at one end, drawing off the residual gases at the other, he would have improved his method, and escaped many inconveniences.

If one views the gigantic scale in which this manufacture is carried on at the present day, by a Tennant or a Muspratt, he must smile on looking back at the almost puny manner in which they operated in former times; but, then, add to their process the continuous system—the introduction of steam into the chambers by Kestner, concentration in the platinum vessels, and Gay-Lussac's column for the recovery of the nitrous gas—and manufacturers have almost all that could be desired at present.

Much ingenuity has been expended in the construction of every piece of apparatus connected with the manufacture of vitriol. The ovens or burners, the chambers, and every part, have been tortured into a variety of forms, some of which would appear to have been devised in an idle moment, and constructed only to gratify a whim, or if any object has really been in view, it must have been imaginary. But in every manufactory where the process is understood, the difference, except in little details, between the apparatus of to-day and that of twenty years ago, is very small. Improvement after improvement, which have turned out to be rather impediments, have been introduced, had their short reign, and disappeared, only to be succeeded by something else equally visionary. In fact, it would seem that the manufacture of sulphuric acid, though as extensively carried on as any business, yet seems to be the least understood; and the ignorance of some manufacturers appears to be only equalled by that of writers who, in their descriptions of the production of this acid, give figures of apparatus, and vaunt as improvements things which have been exploded for years. It is possible to find, in the works of eminent men, drawings of sets of apparatus for the production of sulphuric acid, *which never could possibly have worked one day*—some, in fact, could never have worked at all.

Production of the Sulphurous Acid.—This first step is effected by burning the sulphur in a close room or oven, commonly called a burner. This burner is a simple erection of brickwork, with an arched roof, as shown in Figs. 573, 574, and 575. The size of the burner is regulated by that of the burner plate or iron flooring, and this latter by the quantity of sulphur proposed to be burned during seven days. The burner plate in the drawing is a rectangular iron, measuring eight feet by four feet. This burner plate is surrounded with a vertical edge or border, standing about an inch high; this border is at right angles to the plate on three sides, but on the fourth side, the one nearest to the door, it inclines outwards at an angle of about forty-five degrees—this is for the more conveniently raking out of the residual dirt and ashes left after the combustion of the sulphur. The door of this burner is simply an iron plate, sliding in grooves in an iron framework, and is counterbalanced by a weight hanging at the end of a chain, which passes over pullies.

Fig. 573.

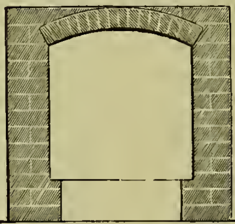


Fig. 574.

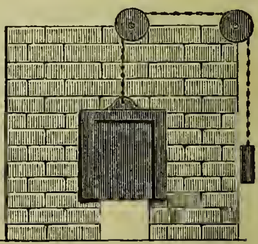
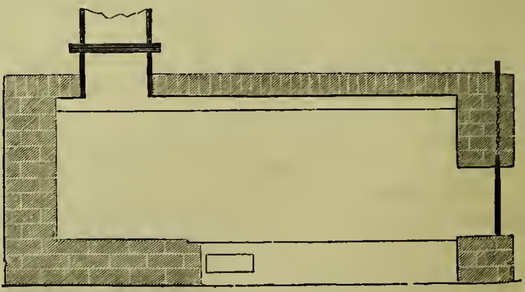


Fig. 575.



As will be seen in the figure, the iron plate does not form the whole of the floor; still the sulphur is burned on it alone. The object of making the burner rather larger than the plate is to avoid, as much as possible, all risk of sublimation. To this end, also, there is a constant current of air passing beneath the burner plates and up a small chimney beside the burner. The opening through which the hot air escapes into this chimney is outlined in Fig. 575, below the burner plate. Four burners, such as this, with the burner plates of the size first mentioned, will easily convert into sulphurous acid one ton of sulphur per twenty-four hours. The quantity for each burner is divided into six portions, one of which is added every four hours.

Burners or ovens have been constructed of iron, sometimes with double sides, so as to include a sheet of air between the two plates. By this means the burners could be kept at almost any desired temperature; an arrangement could be made for causing a circulation of air if the burner should get too hot, or, on the contrary, should they get too cold, this air could be kept stagnant, and being a very bad conductor of heat, the burner would be allowed to rise to the desired temperature. It may be remarked here, that a burner should be kept so hot that each charge of sulphur, as thrown in, will ignite without any fire or heat being applied.

Iron ovens or burners have, however, almost disappeared, as they last a very short time. They gradually corrode, break into holes, and shortly become useless.

Some years ago a patent was taken out for a burner, the peculiar feature of which was its economizing, and converting to a useful purpose, the heat given off by the burning sulphur. The apparatus was very simple. It consisted of an ordinary two-flued steam boiler, for the usual fire-place of which was substituted a burner plate on which to burn sulphur. It was anticipated that by this means sufficient steam would be generated to supply the chambers. Whether it answered the desired end or not is not very clear; but from the fact that none appear to be in operation, it may be inferred that, if in use at all, it is not generally successful. In fact it is very probable that the action of the acid gases upon it would speedily destroy it, as it does the iron burners.

Combustion of Iron Pyrites.—Sulphur, *per se*, is not the only source of sulphurous acid for sulphuric acid. About the year 1835 the then King of Sicily thought fit to impose such a heavy duty on all sulphur exported from his kingdom, that the price of this article rose to an unprecedented height. It is said that at this crisis Dr. THOMAS THOMSON proposed the employment of the iron pyrites, with which different parts of this kingdom abound, as a source of sulphur. PARNELL states that Mr. HILL of Deptford was the first to employ this mineral, for the use of which he took out a patent in 1818. Since that time pyrites has come into very general use amongst one class of sulphuric acid manufacturers. The great objection to the use of pyrites lies in its containing a considerable amount of arsenic. This renders the vitriol objectionable for certain purposes, but this impurity does not prevent its being used by the alkali manufacturers. A manufacturer of vitriol for sale would, were he to use pyrites, very likely have a quantity of his acid returned to him, and he would presently have to stop his manufactory. Not so the soda manufacturer; he is his own vitriol consumer—he uses all the acid he makes for the decomposition of common salt in the first step of soda-making. In his case the arsenic does not interfere in the least, it passes off as chloride of arsenic—As Cl_3 —with the hydrochloric acid gas, and condenses into a liquid state with this latter body. Again, most manufacturers of soda are also manufacturers of chloride of lime. In this case they use up their own hydrochloric acid, employing it for the production of chlorine, which is absorbed by hydrate of lime, forming the bleaching powder of commerce. If a little of the arsenic should pass over with the chlorine, it would be absorbed by the lime, forming an insoluble compound, arseniate of lime, which would fall out, with other useless matters, when the bleacher came to make his solution. The greater portion of the arsenic would remain with the chloride of manganese, and as at present this is a useless product; it is run into the nearest gutter or sewer.

The burning of pyrites is not quite so simple a matter as the burning of sulphur, as a red heat is required. Two varieties of pyrites are ordinarily met with. One kind, of which large quantities are to be found in Wicklow, Ireland, and is imported into this country, to a considerable extent, for the use of sulphuric acid manufacturers, has the crystalline form of a cube, and is of a bronze-yellow color, very hard, so much so as to strike fire with steel. The following is the composition of a specimen, on the authority of R. D. THOMSON—

	Centesimally.
Sulphur,	47·41
Iron,	41·78
Copper,	1·93
Arsenic,	2·11
Silica,	3·93
Zinc,	2·00
Insoluble matter,	1·43

This specimen is of a much richer kind than that usually obtained from this source. The proportion of sulphur very rarely exceeds thirty per cent. This ore contains protosulphide of iron in considerable quantity. The other variety of pyrites occurs in coal beds, and, in fact, is commonly known as coal brasses, fragments and seams of this mineral, may often be seen in coal, and, from their metallic and brassy appearance, have often misled the ignorant into thinking them of much greater value than they really are. According to the just quoted authority, they have the following composition:—

	Per cent.
Sulphur,	53·35
Iron,	45·07
Manganese,	0·70
Silica,	0·80
Loss,	·18
	100·00

A variety of pyrites, known in the trade as Spanish pyrites, has of late been much employed. This is much richer in copper than the Wicklow species. On the introduction of this mineral, it was usual for the sulphuric acid manufacturer to engage to return the spent or burnt material, for the purpose of having the copper extracted.

The general formula of either variety, when free from impurity, is $Fe\,S_2$, that is, one equivalent of iron combined with two equivalents of sulphur, the chemical name of this compound being bisulphide of iron.

This mineral, when heated red hot, with access of oxygen, speedily loses the second equivalent of sulphur, being reduced to a simple or protosulphide—$Fe\,S$—the evolved sulphur being converted into sulphurous acid. If these favorable conditions are continued for a sufficient length of time, the second equivalent also becomes converted into sulphurous acid, sesquioxide of iron remaining. The whole decomposition may be represented as follows—

$$2\,(Fe\,S_2) + 11\,O = Fe_2\,O_3 + 4\,SO_2.$$

As may be imagined, the ordinary burner, as used for sulphur alone, lately described, is not adapted to burn pyrites; a burner of peculiar construction is required. The burner for this purpose is, in general structure, not unlike a lime-kiln. In the case of burning sulphur itself, the object is to spread a layer on a flat plate, so that, when fused and burning, it exposes a large surface for the current of air to sweep over; this is necessary on account of the fusion of the sulphur. But pyrites does not fuse except at a very high heat. The pieces retain their shape; and as it is imperative that they shall attain a red heat, it is necessary to burn them in such a manner that a mass of them can be kept together.

Fig. 576.

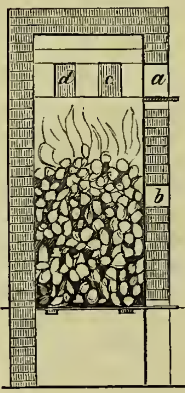
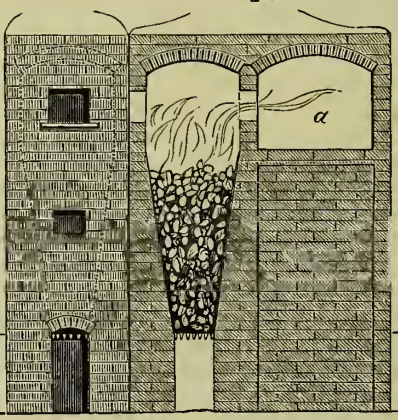


Fig. 577.



The structure of a pyrites kiln is shown in Figs. 576 and 577. In Fig. 577 the pyrites is shown as inclosed on two sides by two sloping walls, the back and front walls being vertical. The mass of pyrites rests on iron bars in the same manner as an ordinary coal fire, the air rushes up from what, in the case of an ordinary furnace, would be the ash-pit, and wends its way through the crevices and interstices of the mass to feed the combustion. The sulphurous acid from the first kiln passes over the next in the direction of the arrows, the gases from both flowing into the general passage, *a*, leading to the chamber. This general passage is often made of a considerable length, usually of from thirty to forty feet. This extreme length is for the purpose of arresting, as much as possible, the passage of arsenical vapors. The arsenic falling in a solid state is removed from time to time. Fig. 576 is a view of one of these kilns looking in another direction, endwise; *a* is the charging door through which fresh supplies of the mineral are thrown in at stated intervals. This door is kept closed, except for this purpose. At *b* another opening exists, but this is usually closed temporarily with bricks—it is only occasionally used. Sometimes the combustion goes on at a rate so rapid that the pyrites becomes fritted, or enters into a semifused state. Sometimes the whole mass gets fused together by its points of contact. In such a case the brick closure is removed for the purpose of introducing a crowbar, or other such instrument, in order to break up the mass or create a passage through. The coal pyrites is much more liable to this mishap than the Wicklow variety, partly on account of the bisulphide contained in it being actually rather more fusible, and partly because the coal brasses contain a certain amount of bituminous matter, which, in burning, raises the heat of the whole mass to a higher point than the Wicklow kind ever attains. The orifices, *c* and *d*, are those through which the sulphurous acid passes either into the next kiln or into the general passage.

It is not usual to see an isolated single pyrites kiln; there are often a number at work. Two are placed at the back of those shown in the drawing, forming a solid square. This answers a double purpose—it economizes brick and iron, and conserves the heat.

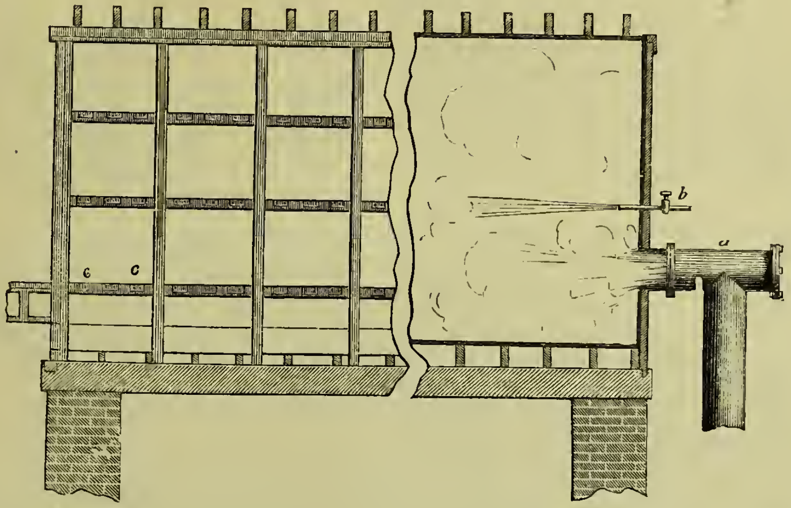
When commencing to burn, it is necessary to make a fire of coal or coke within the burners, having previously closed up the passage or entrance into the chamber, and opened one into the outer air. This fire heats up the sides, *et cetera*, of the kiln, high enough to ignite the pyrites when thrown in. The first few charges of pyrites are often mixed with coke to assist the combustion, until the whole mass has attained a red heat throughout. The carbonic acid resulting from this can do no harm.

The residual mass left after burning, and which consists principally of sesquioxide of iron mixed with more or less protosulphide, was at one time rather an annoyance than of any value to the manufacturer; but at the present time many of them have erected furnaces for the express purpose of extracting the small per centage of copper which it contains.

The quantity of sulphuric acid obtained from a given weight of pyrites of course cannot be as much as from sulphur, inasmuch as pyrites, to take a general average, will not contain more than forty per cent. of sulphur; as a rule, a corresponding amount of sulphuric acid is not obtained from it. Much care and attention is required to burn pyrites well. It is no uncommon thing to find, on examining the waste pyrites heap of a manufacturer, that a great quantity has been removed little more than half burned. On breaking a lump a core or kernel of raw mineral may often be found; whereas well burned pyrites should not contain more than two and a half to three per cent. of sulphur. Any amount more than this is in fact so much material thrown away.

General Construction of the Vitriol Chamber.—Having described the preliminary steps, the Editor now passes on to the chambers themselves. These have undergone many modifications. The chamber, as generally constructed, is simply a large room with leaden walls. A portion of one is shown in Fig. 578. These walls are generally formed of what is technically termed five-pound lead—that is, sheet lead weighing five pounds per square foot—which walls are held up by a suitable framework of wood, to which they are fastened by what are called straps. These straps are pieces of lead, varying in number and size according to the dimension of the chamber. They are soldered or fastened by one edge to the sheet or sheets of lead forming the chamber side. The outer edge is pulled out over the wooden cross bar, and there nailed as shown at *a*, Fig. 578. The joints of the sheets of lead forming the chamber were formerly soldered with ordinary solder; but this entailed a long series of annoyances in consequence of the action of the acid on the solder. The chamber leaked perpetually, and great inconvenience resulted. Eventually the expedient of welting was hit upon. This consisted in rolling the two edges of the sheets together and beating this flat; but this at last gave way to the method at present followed, *videlicet*, fusing the two edges of the sheet together by means of the oxyhydrogen blowpipe. For this purpose an apparatus is constructed which furnishes a constant and pretty strong current of hydrogen gas. This when mixed with a proper amount of atmospherical air projected from a pair of bellows furnishes the blowpipe. To use it the workman proceeds as follows:—He lays the edges of the two sheets together as closely as possible; every particle of dirt and oxidized or tarnished surface is scraped off; the flame is now applied in a peculiar manner, acquired by practice, and the two edges are joined together; thus making a solid joint of pure lead, as incapable of being acted upon as any part of the sheet. The plumbers who undertake the erection of these chambers are able to join two sheets of lead together even when the joint is in a vertical direction; but as it is rather a difficult and tedious business, they contrive to do as much as possible of it in a horizontal direction.

Fig. 578.



No rule can be given for the shape or dimensions of a chamber. Manufacturers are guided partly by convenience, partly by the size of the lead sheets procurable, and partly by a desire to have as much space as possible included in the chambers with the least expenditure of lead. It is with this view that many chambers of vast size, and in shape as near as possible a cube, are being built. Of course, the nearer a chamber approaches a cube in shape, the more absolute chamber room is gained for the lead expended. It is now becoming usual to build chambers of enormous size, with the view of economizing lead. In order that a comparison may be drawn between the old mode of manufacturing sulphuric acid, and the way of proceeding at the present time, some dimensions of chambers at present in work may be given; but it is generally admitted that the best produce is obtained from a series of small chambers, in which one would burn equal to a ton of sulphur *per diem*.

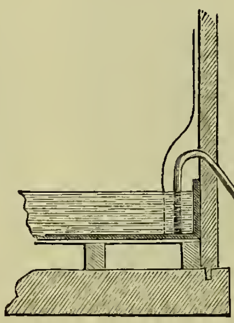
Mr. SCHOLEFIELD, chemical manufacturer, of Bradford, near Manchester, possesses a chamber of the following dimensions — seventy feet long, thirty-five feet wide, and thirty-five feet high; thus possessing the enormous space of eighty-five thousand, seven hundred and fifty cubic feet. The same gentleman has also another large chamber, rather less than this one. It is forty feet long, thirty-five feet wide, and twenty-five feet high. Mr. SPENCE, also, of Newton Heath, alum manufacturer, has a fine chamber of the following dimensions: seventy-five feet long, forty feet wide, and forty feet high; containing, of course, one hundred and twenty thousand cubic feet of internal space.

These are not the only ones—chambers of similar magnificent dimensions are being built in many parts of Lancashire; and at Flint, North Wales, at the gigantic factory of MUSPRATT BROTHERS and HUNTLEY, chambers are of the following dimensions: one hundred and forty feet in length, twenty-four and a half feet wide, and nineteen and a half feet high; the internal space being therefore, sixty-six thousand, eight hundred and eighty-five feet. The above instances are singled out as illustrations of the chambers of the present day.

It will be easily understood that the size of the chamber, or rather the chamber space, must bear some relation to the sulphur burned. Some manufacturers are more successful than others in this respect, being able to produce more vitriol in rather less space than others, probably owing to some variation in working. In a Lancashire work, possessing chamber space to the extent of one hundred and twenty-four thousand, two hundred and sixty-eight cubic feet, they are able to convert eighteen tons of sulphur into sulphuric acid per seven days, the chambers being arranged in the form shown in Fig. 580, to be referred to hereafter. It may be well to notice, that when working with plenty of chamber space less nitre is needed. The reason will be seen when the theory of the action in the chamber has been studied.

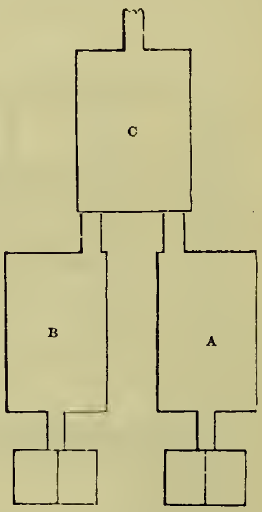
As a general illustration of the construction or principle of a sulphuric acid chamber, it may be said to resemble a bell-jar, as used in the ordinary manner for gas experiments. In this case the bottom resembles a large square basin, into which the chamber appears to have been inverted, like the before-mentioned bell-jar in a saucer of water. This is shown in Fig. 578. The height of this basin edge, or turn-up, as it is technically termed, is about twelve inches. Into this, as in the figure, the side dips, and a light water lute joint is produced. By pushing the chamber side a little inwards—as in Fig. 579—from the turn-up, a space is formed in which the shorter leg of a siphon can be put, for the purpose of drawing off the contents of the chamber as wanted.

Fig. 579



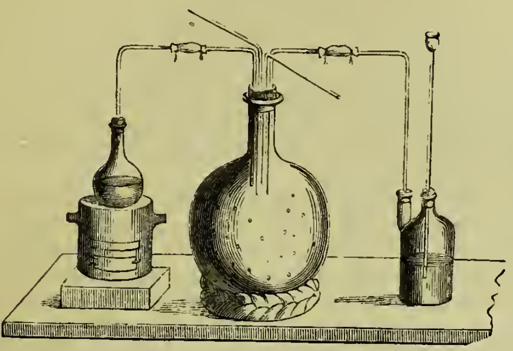
It is seldom that one single chamber is worked by itself, at any work, unless it be a very small one. The usual plan is to work a greater or less number from one into another. An arrangement is figured in PAYEN'S work, in which some five chambers are represented as forming a battery, the gases proceeding from one to another through the whole series. But it is not usual to see such a number connected together. In this country, at least, the number is often limited to two or three chambers working into each other. This answers very well. A favorite arrangement is shown in Fig. 580, which represents three chambers connected together. The chamber, A, has one or two burners attached to it; the same with chamber B. The gases generated in these ovens rise through a cast-iron stalk or chimney into A and B. The portions which escape condensation into these chambers, are conveyed through the passages shown in the drawing into C—the third chamber. If any residue remains it passes with the waste gases into the chimney, through the tube at the end.

Fig. 580.



Theory of the Production of Sulphuric Acid.—The production of sulphuric acid in the chambers is the result of a series of rather complicated reactions. It was sufficient for the old manufacturers to know, that certain bodies placed in certain relative positions produced sulphuric acid; but for the present day this is not sufficient. The reactions of the different gases and vapors on each other, have been repeatedly studied, and much difference of opinion exists on this head. The reactions are very curious and interesting, the chief being the remarkable and useful property of the nitrous constituent of the chamber gas—of acting as a carrier of oxygen to the sulphurous acid. Were nitric acid capable of yielding up at once the whole of its oxygen to the sulphurous acid, it would require eighty-five parts of nitrate of soda to furnish nitric acid sufficient to oxidize the sulphurous acid produced from eighty parts of sulphur, so as to convert it into sulphuric acid. But in practice one hundred parts of sulphur are converted into sulphuric acid with the aid of from five to ten parts, according to the way of working, of nitrate of soda. This is rather startling; but chemists have traced out the fact, that though atmospheric oxygen is itself incapable of at once combining with sulphurous acid, eventually it is from this source that the extra oxygen is supplied. The reaction may be studied on the small scale by the aid of the apparatus, Fig. 581, which may for the purpose be considered a sulphuric acid chamber in miniature. This apparatus consists of a large flask or balloon. In this the action is to go on, the flask is to furnish sulphurous acid, while the WOULFE's bottle is for the production of nitric oxide by the action of nitric acid on slips of copper. Tubes from both these pieces of apparatus conduct the respective gases into the large globe, which globe has also two other tubes inserted through its perforated cork—one is for the purpose of introducing atmospheric air, while the other is the exit pipe for the residual gases, *et cetera.* The apparatus is set to work in the following manner :—A small quantity of water is introduced into the large globe. This is turned about until the sides have been wetted. Copper turnings are placed in the two-necked bottle and in the flask, and the whole apparatus is fitted together as shown in the drawing. An ounce or two of strong sulphuric acid is now poured on to the turnings in the flask, and heat applied ; as explained under sulphurous acid, this gas begins to be evolved. When a steady stream begins to be given off, a quantity of commercial nitric acid, diluted with about half its bulk of water, is poured into the WOULFE's bottles through the tube funnel with which it is furnished. A stream of nitric oxide—NO_2—begins to be evolved immediately. This, soon as it comes in contact with the air in the globe, takes up another equivalent of oxygen, becoming peroxide of nitrogen—NO_4. A reaction now ensues between this and the sulphurous acid from the flask. The NO_4 combines with the SO_2—sulphurous acid—forming, it is supposed, a compound having the following formula—$NO_2\ 2\ (SO_3\ 2\ HO)$—water being present; or to follow the decomposition—

Fig. 581.



$$NO_4 + 2\ SO_2 = NO_2 + 2\ SO_3.$$

This, added to another equivalent of sulphuric acid already formed, the product of a previous action, makes up the formula before given. This latter body makes its appearance as an icy crust on the sides of the globe. Join one of the two open tubes on to a gas holder, or aspirator, and cause a small current of air to be drawn or forced through, to replace the oxygen absorbed by the nitric oxide—NO_2; remove this when done, and join on a small retort, or flask containing boiling water; and now drive a small jet of steam into the balloon. Immediately the steam enters, the frosted coating will melt off the sides and decompose, streams of acid will run down the sides of the globe, and the whole interior will become filled with red fumes. If thought proper, the experiment can be repeated; it is only necessary to throw in a fresh quantity of sulphurous acid. This will again decompose the peroxide of nitrogen, forming the same compound as before—thus the experiment can be gone over several times. In this experiment, it is generally supposed that one has in miniature the action of a chamber; but this is scarcely the exact truth, inasmuch as the circumstances, though very nearly, are not quite the same as on the large scale; and daily experience teaches, that a small difference of circumstances will sometimes produce a great difference in a reaction. In the vitriol chamber itself, all the necessary re-agents are present at the same time, so that it is not unreasonable to suppose that some variation from the above described experiment may take place.

Almost every chemist who has studied the subject, has taken a different view of the question ; though all appear to concur in supposing that the formation of the crystalline compound precedes the formation of any sulphuric acid. On this account most ingenious theories have been broached, explanatory of the decomposition which ensues. All concur in the opinion that it is nitric oxide which is evolved when the crystals come in contact with the water. With a view to elucidate the subject, these crystals have been repeatedly analyzed, but the analyses differ much. Dr. THOMSON gave their composition as—$3\ SO_2 + 2\ SO_3 + NO_5 + HO$—a scarcely probable combination. Dr. HENRY again, from his examination, considered them to be composed of—$5\ (SO_3\ NO_3) + 5\ HO$—a more likely supposition. The analysis of these crystals must always be a difficult matter. It is impossible to procure them absolutely pure ; and even were they obtained pure, they are so very prone to decomposition, that it is almost as difficult to keep them so for the purpose of analysis.

The theory of the chamber reaction just given, and which first originated with CLEMENT and DESORMES, is the one held by many chemists, including KNAPP, who gives it in his *Technology ;* but there are others who hold that the decomposition and recomposition of nitric acid is an essential part of the chamber reactions. Amongst these latter may be named PELIGOT, quoted by R. D. THOMSON. PELIGOT considers that there are four phases in the process. The first is the mutual reaction of sulphurous acid and nitric acid, the products being sulphuric acid and peroxide of nitrogen —$SO_2 + NO_5 = SO_3 + NO_4$. Two equivalents of this NO_4 combine, forming nitric acid and nitrous acid—$2\ NO_4 = NO_5 + NO_3$. This nitrous acid again, under the influence of water, is decomposed into nitric acid and binoxide of nitrogen—$3\ NO_3 = NO_5 + 2\ NO_2$— which two equivalents of binoxide of nitrogen unite with two equivalents of free oxygen, becoming once more peroxide of nitrogen, which eventually becomes nitric acid by a repetition of the last three decompositions just traced out. The nitric acid formed at these several stages acts, of course, exactly as in the first instance. Nitric acid is very easily decomposed by sulphurous acid. This may be illustrated by wetting the interior of a bell-jar with nitric acid, then placing it over a capsule of burning sulphur, and setting on a tile or plate; in a few seconds the jar becomes filled with red fumes, the sulphurous acid having abstracted a portion of oxygen from the nitric acid, reducing it to peroxide of nitrogen.

It has thus been attempted to indicate a possible means of one portion of nitric acid or nitrous gas acting *ad infinitum*, converting an almost endless quantity of sulphurous acid into sulphuric acid, without being itself diminished. Notwithstanding the amount of study and labor bestowed on this question, it is doubtful whether chemists have arrived at more than an approximation to the actual reaction in the chamber. When the very changeable nature of all the bodies which there react upon each other is considered, one can scarcely hope to attain the actual truth. The explanations just given of the formation of sulphuric acid, though doubtless such as take place, are probably only two of many; it is likely that a variation in the action of these bodies on each other is perpetually taking place, as there is a deficiency or an excess of nitrous gas, more or less steam, a greater or less quantity of atmospheric air present, a higher or lower temperature, and many other causes may vary these changes; yet one has a tolerably clear view of the general mode of action. It is a general and wide-spread opinion, that the formation of the crystalline body invariably accompanies the formation of sulphuric acid; whereas in practice its appearance is only accidental. That these crystals should be constantly formed under the ordinary working condition of the chamber is almost impossible, when their great instability when in contact with water is considered, and, as in the atmosphere of a chamber properly worked, a great amount of aqueous vapor always exists, their formation is not very probable; for one can scarcely imagine that a body can be produced under such circumstances, that, were the same body ready formed to be so placed, it would be decomposed. Still, these explanations serve to show how it is possible for a small quantity of nitric acid or nitrous gas to convert a large quantity of sulphurous into sulphuric acid, acting as a carrier between the oxygen of the chamber and the sulphurous acid, constantly taking from one and immediately delivering up its plunder to the other. In order to understand the extent of this action, a previous statement must be remembered of the amount of sulphuric acid which a given weight of nitre could produce, were its oxidizing powers limited to the oxygen contained within itself. It is only from this view that the beauty of the chamber reaction is seen; and perhaps no other metamorphosis is, when looked at in a scientific point of view, so beautiful. It is the hinge and turning-point of the whole manufacture; for were it not possible to produce such a large amount of vitriol with the expenditure of such a small quantity of the most expensive ingredient, the commercial value of vitriol would of course be proportionally higher; and as this acid is the starting-point of almost every other chemical salt or body manufactured, these various salts, *et cetera*, could not be produced nearly so cheaply as at present. As a result of this, the value of all printed and dyed goods would be considerably enhanced, and would be placed out of the reach of many, or at least not easily attained. On the cheapness of this class of articles also, industry in many places depends; so that one may trace much of the trade and prosperity of the country to this beautiful, if not very simple reaction; for though it is possible to produce sulphuric acid without the intervention of nitric acid, none of the methods which have been proposed for the purpose, have gone much further than a laboratory experiment. In a later portion of this article some of these methods will be given.

Having now followed the theory of vitriol-making on an experimental scale, the subject next to be considered is the actual manufacture in the chambers The construction, *et cetera*, of these, and their various appurtenances, has been already noticed. The chamber arrangement described previously—Fig. 578—has two burners to each chamber; that is, to each of the chambers, A and B. The mode of working these burners is such that a constant stream of gas is sent into the chambers. In order to effect this the burners are charged alternately. Thus, if the two burners attached to a chamber be designated A and B, they are charged at the following hours:—

Burner A.		Burner B
Charged at 6 A.M.	....	Charged at 8 A.M.
" 10 A.M.	....	" 12 noon.
" 2 P.M.	....	" 4 P.M.

The same proceedings are gone through with respect to the other two burners. By this mode of charging alternately, it is supposed that as the combustion in one burner loses in intensity the other increases, and *vice versa;* so that a stream of equal volume, or nearly so, is kept up during the whole time.

The burners are charged at the above intervals with a weighed or measured quantity of sulphur. The workman lifts the sliding door, and throws in the charge. Previously to this he inspects the state of the chambers, to enable him to judge what quantity of nitrate of soda he shall decompose simultaneously with the combustion of the sulphur. He puts as much nitre as he thinks necessary into one, two, or more hemispherical iron vessels, or cups, technically termed nitre pots. Immediately he has thrown in the sulphur, he closes the door to prevent the escape of gas; he then proceeds to add to each pot already containing nitre, as much sulphuric acid—from a vessel placed for convenience near the burner—as he considers necessary. This is not a nice or exact operation, the chief point being to add rather an excess of this acid, so as to insure the total decomposition of the salt, leaving a bisulphate of soda, or a mixture of neutral sulphate and bisulphate. When these pots are charged, the door is again opened, and the workman in charge lifts the pots by means of an iron hook, constructed for the purpose, and places them in the burner, in the midst of the now partially ignited sulphur. After a while the sulphur is in a gradually advancing state of thorough combustion, and considerable heat is evolved, which, acting on the nitre pots, causes the complete decomposition of their contents; the nitric acid is given off, and passes simultaneously with the sulphurous acid into the chamber. A method common on the Continent, but rarely now, if ever, practised here, is the employment of strong liquid nitric acid, contained in basins, and placed inside the chamber at different parts on glass and porcelain triangles. Prefixed to the working chamber is another small one, through which the whole of the sulphurous acid has to pass, while in it are placed a number of earthenware dishes, containing nitric acid. In some instances they are not exactly dishes, but pieces of earthenware apparatus, constructed for the purpose, over which nitric acid is trickled in a slow stream. In either case the object is to expose as large a surface of nitric acid to the action of the sulphurous acid as possible. These two bodies, reacting on each other, produce gases which are carried forward to the working chamber. A rather peculiar arrangement is necessarily employed in order to get the nitric acid into the trays. This consists usually of a number of glass siphons, set into carboys of the nitric acid. These siphons convey the nitric acid into another glass apparatus, of which a bell-jar forms a part; the object of the whole being the conveyance of the nitric acid into the interior of the chamber without allowing any gas to escape. The whole affair is by no means simple, and would scarcely suit the manner of working in this country, as, from its construction, it must be very liable to derangement or destruction. Apart from this, it is not very evident what advantage is to be gained by using the nitric acid arrangement. In the first place, there is all the loss from escape, *et cetera*, incident to the manufacture of nitric acid, as well as the cost for labor, *et cetera;* while, by decomposing the nitrate in the burner, this are economized. Nothing can escape uncondensed, as in making the nitric acid every particle of vapor must pass into the chamber. The combustion of the sulphur affords the necessary heat, while the same labor suffices. On the other hand, it would appear at first sight that by this method the amount of nitrous gas necessary for the chamber could be more nicely regulated; but, on consideration, this advantage appears doubtful, for there would be a difference in the quantity passed through, according as the carboys were full, or otherwise, and the taps could, by a little carelessness of the workman, be left running when there was no occasion for them. Such occurrences have taken place to the destruction of the sides of the chamber.

The only part of the nitre system, if it may be so termed, which appears open to objection, or which may be cavilled at, is the contact of the nitric and sulphurous acids at a high temperature, and in consequence the possible decomposition of the nitric acid either into nitrous oxide or nitrogen, both totally inactive, and for the required purpose wholly useless gases. That such a circumstance has taken place is inferred from a fact which occurred in actual practice. A set of burners were worked to their utmost consumption; they became very hot, and required much more nitrate to keep the chamber in proper working order than previously. It would be difficult, in fact almost impossible, to prove the truth of such an opinion; but, nevertheless, it is possible, and from the above incident probable; but if, for the sake of argument, the truth of this opinion be admitted, this appears, as far as practice goes, to be the only objection to this method of supplying nitrous gas to the chambers.

A Continental chemist, who employed the nitric acid process, saw the nitre process during a visit to this country, and on his return substituted it for the one he was previously employing; by so doing, he effected a saving of one-third of his nitrate of soda. This result could not have been obtained if there had not been some gross error or carelessness in the mode of working by nitric acid. It is possible that little care was exercised in the manner of working, and that, on employing a fresh process, more attention was directed to the subject; in either case the person was perfectly satisfied with respect to the advantages of working by the English method.

As before stated, however, the heat of the burning sulphur effectually drives off the whole of the nitric acid of the nitrates in the pots, leaving sulphate of soda. The nitric acid as soon as evolved comes in contact with the sulphurous acid from the burning sulphur, and is instantly decomposed by it; often, on looking into the ovens or burners, the whole of the upper portion appears filled with ruddy fumes. These, together with the sulphurous acid, pass up the stalk or chimney which conveys them into the chamber, there to react further upon each other, so as to produce sulphuric acid.

It has been attempted to be shown by the detail of the reactions on a small scale that, theoretically, one portion of nitrous gas is capable of converting sulphurous into sulphuric acid almost indefinitely, were it not that certain practical difficulties intervene; for instance, it must be apparent to the student of these experiments, that although one portion of nitrous gas can go on continually carrying the oxygen of the chamber to the sulphurous acid, yet this action must necessarily stop when the oxygen is exhausted. And this is possible, for were a close chamber taken, containing a limited portion of oxygen with the requisite nitrous gas, and the operator kept on introducing sulphurous acid, it would be found, on testing from time to time, that the quantity of oxygen was slowly diminishing, and that at length it had disappeared altogether.

This could easily have been the case with one of Dr. ROEBUCK'S close chambers, worked on the intermittent system. To supply this, it is usual at the present day to admit such a constant current of air, that there is sufficient to supply a stream of oxygen over and above what is requisite for the combustion of the sulphur; this finds its way into the chamber, there to effect the necessary change. This oxygen becomes gradually appropriated by the sulphurous acid, as the current of gas keeps slowly moving towards the exit with a regular and constant motion; and as this appropriation never ceases, necessarily the gases on passing out must get poorer in oxygen in the ratio of their nearness to the exit pipe. And this is found to be the case, for if a portion of the gases from this spot are collected, and the slight amount of sulphurous acid and nitric gases removed, the quantity of oxygen in the residue will be found to be considerably less than in common air. The quantity found differs even in the same manufactory, as no rule controlling the quantity of air to be admitted exists. In fact, it is considered advantageous to diminish it as much as possible, so as not to take up the space of the chamber with a useless superabundance of air. But whether this is judicious or not is matter of opinion ; however, the reader is requested to bear in mind that, as before shown, the nitrous gas reaches the exit pipe unimpaired, and passes out with the residual nitrogen, excess of air, carbonic acid, and other matters. This is particularly mentioned, as this part of the subject will be again referred to, with respect to the method now in pretty general use for the recovery of this nitrous gas, and its replacement in the chambers, in order again to commence its labor. This invention of GAY-LUSSAC'S is the only improvement of any consequence which has appeared in connection with the manufacture of sulphuric acid for some years; in fact it leaves little to be desired, except the discovery of a material of which to construct the chambers, which, unlike lead, will be indestructible, or at least unacted upon by any of the bodies to the action of which it will be exposed; although, as will be seen in a later portion of this monograph, this problem has been attempted to be solved, its solution has not as yet been successfully accomplished.

Notwithstanding the number of years that sulphuric acid has been, it may be said, a staple manufacture of England, and so much opportunity has existed for studying this process, much misconception as to the true action of chambers exists. The forms, shapes, and other matters in connection with them which have been proposed and built almost exceeds belief—their name is legion; but the prevailing idea, which appears to have actuated many inventors of these ingenious constructions, appears to have been, that the action of condensation in a chamber was simply that of a distillation process; that as the vapor from a boiling liquid in a still or retort condenses on the cold surface of the worm or other refrigerating apparatus, so with a sulphuric acid chamber, the cold walls condensed the acid vapor contained inside. Evidently, with this idea in view, chambers have been built resembling flues; these, having a large surface of cold lead, were supposed to favor the production of the acid by condensing it immediately on its formation. It is related that a clever chemist across the channel constructed a most novel sulphuric acid apparatus. It consisted of an almost fabulous length of lead tube coiled round and round an apartment like a gigantic still worm ; that sulphurous acid and nitrous gas were introduced at the highest end; these reacted on each other, the sulphuric acid when formed passing the whole length of the tube, a constant stream issuing from the other end.

It was not stated what length of time this system continued, but certainly on the face of it not long.

It is no uncommon thing to find long lead flues attached to the chamber, for the purpose of carrying off the residual vapors to the chimney. These flues invariably take a most circuitous course, many times longer than the direct route; and as frequently there is no obstacle or other such reason why the flue should not follow the most direct line, one is inclined to inquire why this latter course was not adopted. If the question were put, the answer would probably be that a steam jet is introduced at the end of this tunnel nearest the chamber from which it issues, and that this length of flue, with the aid of the steam, is expected to condense any vapors not condensed in the chambers. If the product dropping out at the end of this flue be examined, it will very probably be found to be so weak as to be scarcely worth the coals required to concentrate it.

Let the true state of the case be examined. Is it absolutely necessary that there should be a surface for condensation ? Is this necessary in all cases, natural and otherwise? Does the rain cloud, which, perhaps, in one half hour will come down in the shape of a heavy shower, require a surface for condensation. If it did, possibly rain would be more manageable ; but this watery vapor needs no cold surface; it condenses into water, losing the vaporous and assuming the fluid state, without any assisting cold surface. And if this rain cloud be capable of so condensing, is it not possible for the like physical reaction to take place within a vitriol chamber? But further. Is it not probable, or rather certain, that the sulphuric acid in the chambers never was in the state of vapor. Sulphuric acid requires a heat of 620° to convert it into vapor. The highest point of heat a chamber could attain could be no approach to this; probably the heat of a chamber will not exceed 212° in the hottest part where the gas enters. Is it not possible that every atom of sulphuric acid produced passes from sulphurous acid gas to liquid sulphuric acid at once the instant it is formed—that the chamber is filled with myriads of these newly-formed particles—that these float about, and, like globules of running mercury, they gradually coalesce with each other, until they at last form a particle like a rain drop, sufficiently heavy to resist the sweeping influence of the currents which exist in the chamber; and that, finally, this drop falls into the acid on the floor of the chamber. Although it is impossible to see the process, and so prove the truth of this opinion, a very good inference of its justness may be drawn from an experiment which was tried on a chamber. A strip of lead about three inches wide was attached to the inner side of a chamber, in such a manner that it resembled a gutter or spout in an inclined position, one side of this gutter being formed by the chamber side, the other by the strip. This was placed about from two to three feet above the surface of the acid in the chamber, and was about nine feet long. In consequence of this position, the whole of the acid which formed or condensed on that side of the chamber above the strip would flow along it, and be carried by a small tube passing through the wall of the chamber into a vessel placed on the outside to receive it.

If the liquefication of the acid took place almost wholly on the side of the vitriol chambers, a pretty rapid current of acid must have flowed along this arrangement, but this was not the case; instead of, as might have been expected, a constant stream passing along it, nothing more than isolated drops issued, probably at the rate of six drops per minute, an utterly insignificant quantity, when compared with the amount of acid which must have been formed within the space over which this strip had the command.

In fact any observant manufacturer must, after a little attention to the subject, come to the conclusion that such is the case; that condensation goes on chiefly within the space of the chamber, although a small portion may condense on the walls; for when the acid particles are floating about in the chamber—driven hither and thither by the various currents which must exist—some must become attached to the sides and flow down into the acid already at the bottom, adding to the amount already formed. But the argument remains that all the acid is not brought to the liquid state by this means; that, in fact, the quantity thus formed bears a very small relation to the whole.

To many this will be already palpable, but evidently not to all, inasmuch as these strange abortions of chambers are not by any means as yet extinct, but still remain a testimony to the ignorance of many of our manufacturers. It must be apparent, that if anything more than the usual average amount escapes from the chambers, either they are badly worked or overworked. If the first should be the case, more attention must be directed to them to find out the error. If the second suggestion be correct, then, as the chambers have more material introduced into them than they can properly work, the amount of sulphur usually burned must be decreased, until the maximum amount which can be burned with a beneficial result is found. It needs little argument to prove, that the working space included in a tunnel could have been included in the chamber at much less expense.

The introduction of steam into the chambers has been already mentioned. Previously to the use of this reagent, the water on the floor of the chamber had all the work to do; every particle of the sulphuric acid and nitrous compound was compelled to pass in to the water from whatever portion of the chamber it was formed in order to be decomposed. The interior of one of Dr. ROEBUCK'S chambers, or any other chamber worked in the same manner, while in action would have been a pretty sight; the reactions must have taken place consecutively, as described in a preceding portion of this article when treating of the theory of the process. Every particle of sulphuric acid formed must previously have passed through the solid crystalline stage. The interior walls of the chamber must have been each time more or less coated and incrusted with the beautiful snow-like crystals, while the whole interior of the chamber must have resembled a snow-storm in an amber-colored atmosphere. The first manufacturer who introduced steam into his chambers did but exchange a beauty he could not see for a solid reality he could well appreciate. He introduced a most beautiful invention, which not only increased the production in the same chamber-space, but altogether simplified the operation. Instead of, as before, each equivalent of the double compound waiting to fall down into the cold liquid which covered the floor of the chamber in order to be decomposed, leaving, probably, a large per centage of the nitrous constituent behind; the bodies now never assume the solid state but on extraordinary occasions, and then only through neglect. The whole of the reactions take place in a warm wet atmosphere, where everything is favorable to the intended purpose.

Sulphuric acid, when tolerably concentrated, has a tendency to combine with nitrous acid, forming a definite compound to be treated of hereafter; but unless the acid be concentrated, more so, in fact, than it is usually found in chambers, this compound is very unstable in the cold; heat it and the nitrous constituent flies off.

In a chamber worked on the old plan a great quantity of nitrous gas must have remained in the vitriol, causing a great loss of this body—the most expensive material the manufacturer employs. On the contrary, in the chambers of the present day, each particle of acid as formed must, if sufficient steam be present, be of such a density or strength and temperature as to be incapable of carrying down, and thus removing from its proper sphere of action, any of the nitrous bodies present. Again, in the old plan of working, the nitrous gas was only liberated at the surface of the liquid at the bottom of the chamber. Now, peroxide of nitrogen—NO_4—the body into which the nitrous gas would become changed the moment after its liberation, coming in contact with the oxygen in the chamber, is a heavy gas, heavier than common air. It can be floated about and poured from vessel to vessel like carbonic acid. This then, on its being set free, would float about on the surface of the liquid, running the risk of being rapidly absorbed; whereas its sphere of action lies amongst the lighter sulphurous acid, on the upper portion of the chamber, to which point this NO_4 could only be conveyed by diffusion, or be carried up by getting entangled with the upward stream of gases emanating from the tube which conducts the sulphurous acid into the chamber. In the present system, whenever a particle of this peroxide or quadroxide of nitrogen meets one of sulphurous acid a reaction commences. Now there is no necessity for a descent to the bottom of the chamber; water, in the shape of vapor, pervades every part of the chamber; and as quickly as the crystalline combination forms, if it does form under these circumstances, it is as quickly decomposed. The resulting sulphuric acid falls, but the nitrous gas forms a second combination, and is then again ready to perform its purpose the moment it comes in contact with another particle of sulphurous acid. When carefully considered, it will be understood that it is not too much to call the introduction of steam into the chamber a great invention. It is not difficult to imagine how slow the process must have been in the old chambers when compared with the rate at which it proceeds now, and what enormous advantages manufacturers at the present day are possessed of over their predecessors.

Much difference of opinion exists as to the proper density at which the acid should be kept in the chamber, or rather what is the maximum density to which it may be allowed to rise? All manufacturers are aware that it is to their interest to keep up the strength of the acid in the chamber to the highest point possible, for by so doing there is a saving of fuel in the concentration. A writer has lately stated, on the authority of an eminent manufacturer, that it is impossible to keep the vitriol free from nitrous gas if a density of 1·45 or 90 degrees. Twaddell is exceeded; while again in Knapp's *Technology* it is stated, that the maximum density of 1·585, or about 112° Twaddell, should not be exceeded. A considerable margin exists between the two statements, but in such matters as these, which are not found capable of absolute and precise proof, the only course to be pursued is to take for a guide a near approximation to some recognized authority, or perhaps better, to be guided by the result of practice. A set of chambers now at work are kept at a general strength of from 110° to 112° Twaddell. It is not observed that more than a trace of nitrous gas is absorbed, except occasionally, and these instances may invariably be traced to either a slackening or a total cessation of the current of steam, either from the carelessness of the workman or by accident. In either case the pressure of steam has become so low that little or no watery vapor is being thrown in. Perhaps there is no manufacturer who has not at intervals found his chamber acid so highly charged with nitrous gas as to slightly effervesce when poured with violence from one vessel to another; in fact, it is not an extremely rare occurrence, under some circumstances, to find it perfectly green, from holding a large quantity of peroxide of nitrogen in solution. If, when this takes place, strict inquiry be made, it will be found, that such a state of things results from the chamber having been left for some time, possibly for hours, without steam. This point is worthy the manufacturer's attention, as it largely concerns his profits. The chambers, as at present constructed and worked, are not calculated to work on the old plan. As has been stated before, the steam materially quickens the process, and is the means of much more acid being made in a chamber than could be made were it worked on the old plan. When without steam, the excess which the chamber is not able to convert must pass up the chimney, being a loss of its value as well as risk of nuisance or damage. And not only does this occur, but nearly all the nitrous gas which is dissolved in the vitriol flies off when it becomes hot in the concentrating pan, to no purpose but to annoy the workman and surrounding neighborhood. Such a state of things is not an imaginary case, but a fact, as nearly every vitriol-maker can testify, and that to his material cost.

Payen gives a method for economizing this nitrous gas passing from the chamber dissolved in the vitriol. This he proposes to do by passing a stream of sulphurous acid over the surface of the vitriol while being concentrated; the sulphurous acid liberates any nitrous gas or decomposes any nitrous compound, and becoming mixed up and absorbed into this sulphurous stream, is carried into the chamber. The apparatus for effecting this purpose, though ingenious, renders the process of concentration too complicated, in fact, leaving a doubt whether the economy effected by its use is not more than balanced by the inconvenience entailed by its employment. Most manufacturers have a very wholesome fear of what is called a break down, and the general want of stability which this apparatus appears to have is not likely to make it a favorite.

The Recovery of the Nitrous Gas.—The reader will no doubt have borne in mind, that whilst tracing out the reaction of the chamber it was possible to follow the sulphurous acid until it was completely converted into sulphuric acid, and that during this process the whole of the free oxygen of the chamber may become exhausted, but that, nevertheless, the nitrous gas still remains the same.. This gas does not enter into, neither does it give up, any essential part of itself to the vitriol; its removal is only on account of its passing off with the current of useless nitrogen and other gases, and when removed it still possesses all its active properties, but diluted and incommoded with a quantity of gas of no value. Many have been the attempts to prevent this loss, and to bring this nitrous gas back into a useable form, and this idea has formed the principal feature in many patented improved methods of manufacturing vitriol. Perhaps the most successful worker in this direction was Gay-Lussac, the celebrated French chemist. His process, which was patented in this country, is at present in use in several works, and is found to be perfectly practicable, and to answer well the desired end.

In order that the reader may have a clear general idea of the invention, it is necessary to draw on the imagination a little. Let it be supposed possible to construct a filter through which to pass the unaltered air—nitrogen, trace of sulphurous acid, and nitrous gas—which forms the current constantly passing from a chamber; let this filter have the property of retaining the last-mentioned gas, and of letting all the others pass on to the chimney. When sufficient material has been collected on this filter, let it be possible to remove this retained material and to introduce it into the chamber again, there to renew its former labours, and a view is obtained of Gay-Lussac's invention. It has been shown that sulphuric acid, when tolerably strong, possesses the power of absorbing, retaining, or uniting with certain of the lower oxides of nitrogen. Most if not all works on chemistry treat more or less of these combinations, although not much appears to be known about them. Gay-Lussac studied them to a considerable extent, and perhaps gave the most just account of them; to this study manufacturers are doubtless indebted for the invention. The formulæ of these compounds are given very differently, arising no doubt from the difficulty of separating the different combinations formed, and then of analyzing them. But they appear to be generally considered as compounds of one, two, or more atoms or equivalents of sulphuric acid and nitrous acid, NO_3. Some view them as compounds of sulphuric acid and peroxide of nitrogen, NO_4. But whatever the composition, it is certain that peroxide of nitrogen forced into, or rather passed through strong sulphuric acid, is retained by this acid, and the body in question is formed. This is the principle of the process. It may be performed in miniature as follows: — First, fill a potassa bulb apparatus, or a small Woulfe's bottle with strong sulphuric acid—this is for the absorption—connect this with another Woulfe's bottle containing copper turnings; let a safety or tube funnel be put through a cork in the second neck of this bottle, the other neck being connected by a short length of tube with the absorbing bottle, which also must have two orifices, one of which is to receive a short length of tube leading from the bottle just described to the bottom or lower portion of the sulphuric acid. The second neck must be connected with a suitable aspirator gas-holder. When all is complete, pour a little diluted nitric acid through the funnel on to the copper clippings, having previously set the aspirator at work, drawing a stream of air down the funnel and through the sulphuric acid; after a while, when the action appears to diminish in intensity, pour on a little more nitric acid, still keeping the aspirator at work, drawing the whole current of gases through the sulphuric acid. This must be kept on until the sulphuric acid appears to be becoming saturated; this is indicated by red fumes passing through in quantity. The apparatus may now be disconnected. The rationale, which has been partly described before, is simple. The nitric acid acting upon the copper produces nitric oxide, NO_2. This, immediately on coming in contact with the oxygen of the current of air which is passing through, becomes converted into peroxide of nitrogen, and this is absorbed by the sulphuric acid, forming a compound with nitrous acid, another with nitric acid, being formed at the same time probably as follows:—

$$2\,NO_4 = NO_3 + NO_5.$$

In this experiment the imaginary filtration has been really effected. Excess of air, nitrogen, *et cetera*, have passed on while the nitrous compound has been retained; thus one-half the problem is solved. When the apparatus has been disconnected, empty the bulb apparatus or bottle, as the case may be, into a convenient glass vessel, and pour into a beaker glass a volume of hot water, twice the bulk of the nitrous vitriol; pour this nitrous vitriol slowly into this hot water—a copious evolution of nitrous gas will ensue; in fact, if nearly boiling water be employed, almost all the nitrous gas absorbed will be again given off; a small portion will remain, having formed nitric acid as follows, supposing the liquid to be a compound of sulphuric acid and nitrous acid:—

$$3\,NO_3 = NO_5 + 2\,NO_2.$$

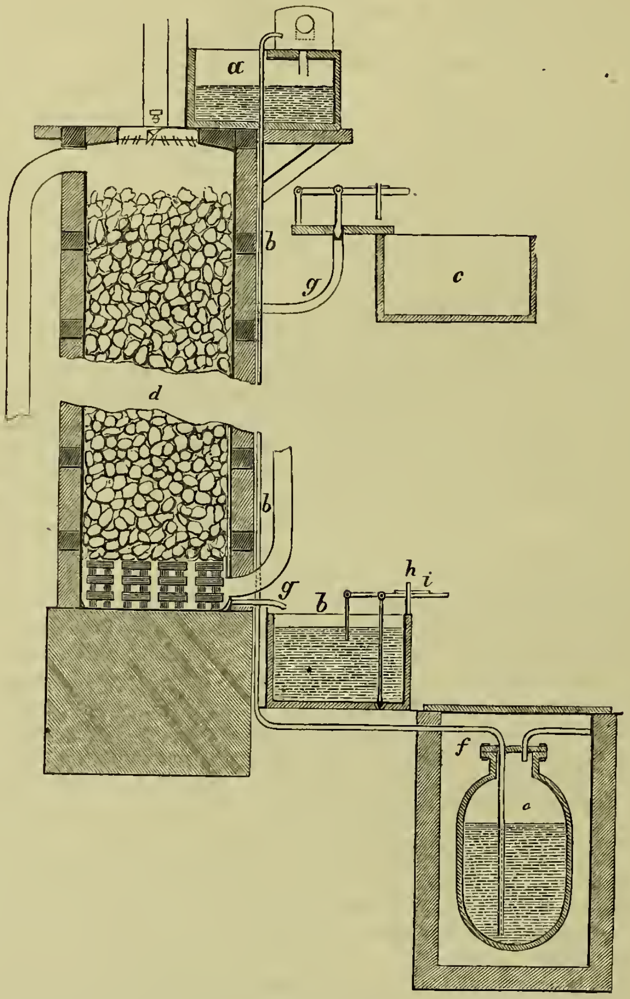
This NO_2 becomes peroxide of nitrogen in contact with the air. The above reaction has been given before in connection with the chamber reaction, but still it is scarcely out of place.

This experiment then is exactly a representation on an experimental scale of GAY-LUSSAC's invention. Sulphuric acid forms his filter, by which he separates the valuable nitrous gas from its useless companions, although not exactly in the manner just given. Columns for the condensation of gases are well known pieces of apparatus in all chemical works. They are usually tall hollow towers, constructed, according to the purpose for which they are to be used, of stone or lead. They are filled with pieces or lumps of any suitable material which offers a large surface, and at the same time are not acted upon by the acids or acid gases, or other corrosive substances with which they have to come in contact. Coke offers many points of advantage in this particular, as it is acted upon in the cold by scarcely any chemical body; and it offers this additional advantage, that while offering more surface than perhaps any other material at all adapted to the purpose, it is at the same time very light. The column to be employed for the absorption of these nitrous gases is filled with coke, and by means of suitable contrivances, to be detailed hereafter, it is kept constantly moistened with a small stream of strong sulphuric acid, which is continually run on to it. The gases from the chambers are made to pass up or through this column or tower on their way to the chimney; and in order to do so, they have to wend their way through the many thousand passages and openings formed by the interstices existing between the pieces of coke. Thus they are split up into numerous streams, and have to come in contact with many hundreds of feet of surface wet with vitriol before they arrive at the exit pipe. The apparatus is built of such size and proportion that the gases in their course upward are brought into contact with sufficient sulphuric acid to absorb the whole of the nitrous gas contained in them. The acid containing the absorbed gas is collected in a proper reservoir or receiver, placed at the bottom of the column for its reception, from thence, as will be seen hereafter, to be removed, in order that it may be decomposed in such a manner that its nitrous constituents may be again used.

This apparatus seldom or never works well when applied on the small scale, as, for instance, when applied to one or two small chambers. This is a practical difficulty which, perhaps, in the hands of a careful and determined person, might be got over. It has been applied on a small scale at several works, and has been given up. On the other hand, several vitriol manufacturers on a large scale who use it, speak very satisfactorily of its performance. In some cases, by its employment, the consumption of nitrate of soda has been reduced from one-tenth the weight of the sulphur employed to one-twentieth—in fact, to the extent of one-half of that previously used. This is certainly a very good result.

The dimensions here given are those of an apparatus which is applied to a set of chambers, in which an average of eighteen tons of sulphur are consumed or converted into sulphuric acid per week of seven days. The apparatus is seen in Fig. 582. It consists essentially of the column or tower itself, three cisterns for holding or containing vitriol—*a*, *b*, and *c*—together with a large close cast-iron cylinder, *d*, employed in raising the vitriol to be used for absorption from the surface to the upper cistern at the top of the column, and also for removing this when nitrated or saturated with nitrous gas. The tower cannot be more appropriately described than as a tall cylinder of lead, five feet diameter, and thirty feet high, supported, like the lead of the chamber, by a suitable strong wooden framework. This leaden cylinder is completely closed in at the top, and stands in a suitable leaden dish or tray at the bottom, of such a depth that it always contains vitriol enough to lute it, and so prevent any escape of gas. The thickness of the lead is from a quarter to half an inch—some manufacturers preferring to use the thinner variety from motives of economy, while others, in order

Fig. 582.

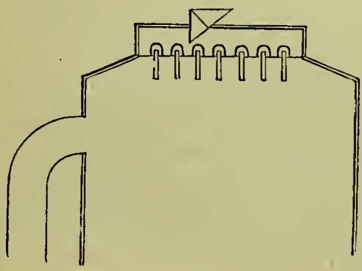


to insure absolute safety, prefer to use half-inch lead. This cylinder, as stated before, and as shown in the drawing, is filled almost completely with large pieces of coke. The quality of this coke is not by any means a matter of indifference: it must be in large firm pieces, for if it is either in small pieces of a rotten or soft variety, it must be rejected; for, if small, sufficient space will not be left between the pieces for the proper passage of the gas, but will choke up the whole apparatus: besides the weight of the coke in the upper portion of the column will crush that near the bottom, and a similar result will follow. It will be, perhaps, well to mention, that if quarter-inch lead is used in the construction of the column, it would be well to line it with thin fire-tiles. These must be applied simultaneously with the filling in of the coke, as it would be impossible to hold them in their places otherwise; they must be placed as close as possible to the lead, and pressed to it, and held in their places by the coke pressing against them. This precaution of brick lining is necessary to prevent—what might otherwise occur—the cutting of the lead by the sharp edges of the coke; for although the column may be quite full at the first, yet, after a while, it will be seen that the whole mass has subsided some inches, has in fact settled down, and were the tiles not in their places to protect it, it is possible that a sharp edge of coke might cut a slit in the lead.

It is necessary to have some arrangement at the bottom of the column by which the gases from the chamber can have unobstructed entrance, for were the coke at once thrown in, without some contrivance for this purpose, it would fill up the entrance pipe, and prevent or nearly so, the entrance of the gases. A very good arrangement for this purpose may be made with fire bricks, which are almost unacted upon by acids. The lower part of the tower or column, to a few inches above the entrance for the gases, is filled in with these fire bricks—arranged in a systematic manner; in fact, built up in the most open and loose manner possible, so as to allow the greatest amount of inlet to the gases. The coke is piled above this. By this arrangement the gases have all but a totally uninterrupted entrance; they rush up through the wide spaces left by the brick, and from thence divide themselves amongst the numerous passages which they find between the coke.

At the top of the column is placed the cistern containing the vitriol, which is run down it. Care should be taken, in the construction of an apparatus of this kind, that the timber work is sufficiently strong to bear the rather heavy weight of this cistern; but this, of course, is what few would overlook. Inserted into what may be called the roof of the column is a device for spreading the vitriol over the whole surface of the coke. In fact a good deal depends upon this, for were the vitriol run on just in one spot, it might possibly find its way down in one small stream not capable of taking up the nitrous gas, in consequence of its having little surface. **Knapp** recommends this spreading to be effected by a series of cones placed within each other; these cones, which, as might be supposed, are constructed of lead, have each the apex removed, and the open ends of the whole system are placed immediately under an orifice in the roof of the column. The vitriol is made to enter these open ends in flushes; it rushes over the surface of the different cones, and finds its way to the interior, wetting the coke with a series of concentric circles of sulphuric rain. This will be understood by referring to Fig. 581.

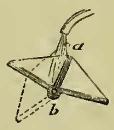
Fig. 583.



A method which answers tolerably well is shown in Fig. 583. This is an arrangement actually in use. It will be better understood by supposing a broad flat dish, about two-thirds the diameter of the column itself, to be placed on the roof of the column. Into this are inserted a number of tubes—about twenty or thereabouts; these tubes protrude both down into the column, and for a shorter distance up into the dish. The under portion of the tube can be bent, so that the stream which it delivers can be directed to any point desired; for instance, let the whole area of the column be mapped out, and twenty different equi-distant spots be marked; a tube is directed over each of these spots, so that when in action the coke is wetted in twenty different places, in this way increasing the chances of the whole body of it getting thoroughly moistened. Whatever mode of attaining this end may be adopted, the use of an oscillating box, or what the workmen, perhaps more expressively than elegantly, term a *tumbling box*, is almost absolutely requisite; for, in the last-described scheme, without such an adjunct the spreading would be very inefficiently performed. The stream of vitriol which is run down a column of this description is, comparatively speaking, very small; and when this comes to be divided into twenty separate streams, they must naturally become very much less; so much so, in fact, that the chances are, that unless the ends of the tubes which project into the basin are exactly of one level, which practically is impossible, some three or four which happen to be the shortest, will take almost the whole of the stream. This casualty is put out of the question by the use of the oscillating box, the action of which is to deliver a comparatively large body of fluid at intervals, and this from a small stream. It is easy to see that each time the box oscillates and delivers, say a quart of fluid, the height of the liquid in the basin suddenly rises, and then immediately subsides, enough fluid having been delivered to furnish a current for each of the twenty different tubes.

It would, perhaps, be well here to describe the construction of one of these oscillating boxes, notwithstanding their being well known, and their action thoroughly understood. It is an old invention, and has been figured and described in many works on chemistry. It is constructed of a shape similar to that of two cones fastened together at the base and sectioned, with an axis connecting the apices; this will be seen by referring to Fig. 584. This apparatus, as depicted, is a diamond-shaped box, open at the two upper, and closed at the two lower sides. The box is divided into two by a partition, *a*, in the centre, and the whole is mounted on an axis, *b*, on which it can oscillate. It works, in this manner, one of the two spaces caused by the division, presents itself to the tap of the cistern, or other vessel, whence a small stream is issuing. It will be seen, by examining the figure, that the fuller one of these spaces becomes, the more to that side must the centre of gravity incline, until at length this centre of gravity gets thrown so far beyond the axis, as to overbalance the empty side of the box. When this occurs, the whole of the liquid which this division contained is emptied out suddenly, and the other side presents itself for filling; the apparatus taking the position indicated by the dotted lines. Of course, in a short time, this side becomes full, when a reverse again occurs, and so on as long as there is sufficient liquid to keep it in motion.

Fig. 584.



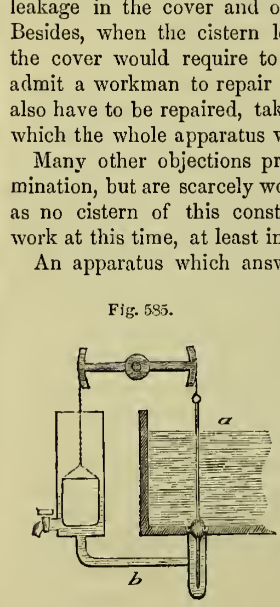
Another point of some importance in connection with the economizing powers of this column, is the regularity of the stream of acid which runs down. If the tap of the cistern, whence the acid flows, is set to a certain speed at the commencement of the space of time during which the acid is to last, it is certain that it will not run at the same velocity when the cistern is getting nearly empty; nor, according to the proper physical law which controls these matters, will it run with the same force during any two portions of time. According to the law, the rate decreases as the square root of the depth; or, to take a practical and easily understood illustration—suppose it is a cistern three feet deep, then whatever the number of quarts, gallons, or other volumes per minute at which it runs, it will be delivering exactly half that number when the cistern has lowered to nine inches deep. Thus at one time there would be running down exactly half the quantity as at another; at one period probably supplying the apparatus with more vitriol than is necessary to take up the nitrous vapors, and at another time not giving it sufficient acid, thus allowing a valuable substance to escape.

This idea appears to have struck either the original inventor, or an early employer of this process; for in Knapp's *Technology*—which appears to be the only book in which a description of this process is inserted—a drawing of a method of obviating the defect is given. It is there proposed to employ a closed cistern, in principle resembling a bird's drinking fountain, where water can only be obtained by replacing the space occupied by it with air; and to cover this cistern with a top constructed of thick lead, supported in the interior by iron rods, sheathed in lead, to protect them from the action of the acid. When working, this apparatus must have had two alternate currents passing through the tap, one current of air into the receiver, to supply the place of the acid flowing out of it into the oscillator.

Several objections to this plan present themselves. In the first place, such a closed cistern must have been very inconvenient to work, in consequence of the increased amount of manipulation; for it was necessary to have an orifice in the cover through which to fill it. This aperture required to be made perfectly air-tight when the cistern was filled; for if this was not done, the whole principle involved became nugatory. Again, the construction of such a receiver must have presented many difficulties, not to speak of the great liability to leakage in the cover and other parts of the cistern. Besides, when the cistern leaked, a great portion of the cover would require to be removed, in order to admit a workman to repair it; the cover itself would also have to be repaired, taking up much time, during which the whole apparatus would be inoperative.

Many other objections present themselves on examination, but are scarcely worthy of remark, inasmuch as no cistern of this construction appears to be at work at this time, at least in this country.

Fig. 585.



An apparatus which answers the desired end very well has been applied; and it has none of the objectionable features just described; it is shown in section in Fig. 585, where *a* represents the cistern containing the supply of acid. Adjoining this cistern is a circular vessel of lead, twelve inches in diameter, and of the same height as the cistern. Between these two, and from the bottom of each proceeds a tube, *b*, which forms a passage between them. This tube is not a whole piece of tube, neither does it take the shortest course between the two vessels, and this for a reason which will be presently shown. The upper portion of the pipe opening into the cistern is of a conical shape, and into this is fitted a conical lead plug, which has been cast on a long iron rod, and turned up in a lathe very smoothly and with great nicety, so as to fit very accurately into its seat, the conical mouth of the tube just mentioned. This plug, as shown in the drawing, has the iron rod, which forms its stem, prolonged below the plug proper some eight or ten inches. This portion, as well as the upper, up to within an inch or two of the hook at the top, is coated with lead. This coating must be done very accurately, to insure the exclusion of the acid from the iron rod. This is best done by pushing the rod through a lead tube of the proper diameter, and fusing the extremities of the upper and lower portion to the plug proper by means of the blowpipe jet, described in that portion of this article which treats of the construction of the chambers. The lower length of the rod moves in the straight portion of the tube below the cistern, and is for the purpose of preventing the plug getting out of its seat, as well as for accurately guiding it in.

Within the tall cylinder before spoken of hangs a leaden bucket, for so it may be most appropriately called; the rim, or upper edge of this bucket, has an iron ring inserted into it, for the purpose of keeping it in its proper shape. To this ring are attached three iron chains, not unlike, in thickness and general appearance, to dog-chains. These chains are attached at a short distance to a single chain, which hangs in the centre of the cylinder. The upper end of this chain is in its turn attached to one end of a lever, moving freely on its axis, situated at the middle of its length. To the other end of the lever is attached another short length of chain, connecting the end of the lever with the hook at the extremity of the plug. This lever has semicircular pieces of iron attached to its ends, over or on which the chains rest, in such a manner that the plug and bucket have each, as near as may be, a true vertical motion, so that the plug may descend exactly into its seat, and that the bucket may move up and down precisely in the centre of the cylindrical vessel. This cylindrical vessel has the delivery tube fastened to it, and the tap from which the stream flows attached to it again.

In order to work effectually, imagine that the apparatus is newly attached, and has not been used before, and that this is the first trial. Let one imagine that the plug has been inserted unattached to anything else into its seat, and also that the cistern is full of vitriol; also determine that the vitriol shall run out at a pressure of some six or eight inches—vitriol pressure, not water. To do this, let the bucket hang down in the cylinder some six or eight inches from the bottom; attach the chain to the lever, and then attach the plug by means of the chain to its other end. In both cases this should be done so that the lever remains in a horizontal position; then let the bucket fall to the bottom. The result of this will be that the plug will be drawn from its seat, and the vitriol will run from the cistern into the cylindrical vessel through the communicating pipe. Now, watch the action of the apparatus as the vitriol rises in the cylinder. As it does so the bucket will rise. Now, as first said, this bucket is fastened to one end of the lever, while the plug is fastened to the other—in point of weight the plug is the heaviest. Under these circumstances it naturally follows, that as the bucket *ascends* the plug descends, until at last the bucket ascends so high that the plug falls into its seat, and effectually closes the passage. If allowed to remain, and if the plug fits well, the liquid rises no higher in the cylindrical vessel. But if the delivery tap be opened the liquid in the cylinder will be seen to subside, the bucket descend, and the plug be lifted from its seat so high that it allows just so much liquid to pass it as is running out through the tap, whatever this quantity may be.

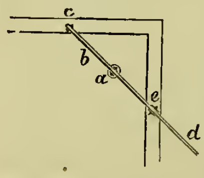
Thus, on examining the action of this apparatus, it will be found that it allows the cistern to be run almost empty at precisely one pressure, either six, eight, or any number of inches, thus obviating the misjudgment of the workman, or, what is probably oftener the case, the total neglect of its rate of running. A careful workman, from constant practice, soon learns to set the tap so that it shall run many hours without altering; he has only to notice the time required to run so many inches out of the cistern, it having a guage with inches marked on it for this purpose; from this he can easily calculate, from the depth of the cistern, whether it will last out the required length of time. If the rate of running is not correct, it must be altered less or more accordingly. As this apparatus is not patented, it may probably find other applications.

Having now described the mode of running the acid down the column, let attention be turned to another and previous portion of the subject—the manner of placing it in the cistern. It is well known, and is a matter of no little regret, that as yet there is no real acid pump. Weak vitriol can be pumped with a pump of the ordinary description—the barrel formed of lead, the valves and all the flexible portions being formed of caoutchouc. But this latter body, and every other body which serves its purpose for ordinary liquids, is destroyed in a few hours, when placed in strong sulphuric acid even when cold. Such being the case, another contrivance is adopted—a very useful although not a very new one, it being at least as old as the chemist's edulcorator, used in analysis for washing precipitates. This apparatus, as is well known, enables one to drive out a rather forcible though small current of water by atmospheric pressure applied on the surface of the water contained in the bottle. This is effected by closing the neck of the flask or bottle employed with a cork through which two tubes pass, one of which descends to the bottom of the flask below the surface of the contained water, while the other merely protrudes below the bottom surface of the cork. By means of the mouth, air is forcibly compressed within the bottle; this, in its efforts to escape, drives the water before it in a stream; and this is the principle of the apparatus by which the vitriol is elevated. A large cast-iron vessel, *e*—Fig. 582—replaces or rather represents the washing bottle. This vessel is for convenience placed in a walled cell or space dug in the ground, and is made of such dimensions that it will hold rather more than the cistern it is destined to fill. It is formed not unlike a soda water bottle, this shape being the strongest, the lower and upper ends being rounded, the latter having a flanged neck cast upon it; this being about one foot wide. This flange has a number of bolt holes cast in it, corresponding to a like number of bolt holes in the lid. The lid has two perforations cast in it through which two two-inch diameter pipes can be passed and be secured, one of which pipes, as in the case of the wash-bottles, passes to the bottom, or nearly so, leaving a space of merely two or three inches; the other pipe merely passes through, terminating beneath the lid. Perhaps the best method of making a secure joint between this lid and the vessel flange is to insert an India rubber ring of such a size that it will lie within the circle of bolts; the ring being thus placed, the bolts are put in and screwed up tightly, thus compressing the elastic washer, and forcing it to fill up every crevice, so as to be effectually air-tight. The whole of this description will appear much clearer on referring to the figure—Fig. 582.

The drawing which accompanies this is scarcely complete, inasmuch as one cistern has been left out; this has been done purposely, so as not needlessly to complicate the figure. In order to explain the drawing the reader must consider himself working the apparatus. In the first place, suppose the iron cistern, *e*—Fig. 582—to be filled with vitriol of the density 1·750, or 150° Twaddell, this being the strength of vitriol to be used in the absorption of nitrous gas. At this moment it does not matter how it was filled. By means of a powerful air-pump, a strong pressure of air is forced on to the surface of this vitriol, driving or forcing it up the pipe, *f*, into the cistern, *a*, which it fills. From this cistern it runs, as has been already described, into the column, where, after traversing the coke with which it is filled, it runs into the dish-like vessel in which the column may be said to stand. From this it runs by means of the pipe, *g*, into the cistern, *b*; it is now by this time saturated, or nearly so, with nitrous gas, which it has gathered during its passage down the tower. From this cistern, *b*, it is once more run into the iron underground vessel; the air-pump is once more put into requisition, and it is forced from this vessel into the cistern, *c*, there to be reserved and run off as wanted, to be decomposed in the chamber.

As before stated, the cistern for the raw vitriol is not included in the drawing, but, as it is only a copy of the one at the foot of the column which is represented, a description of the one will serve for the other; it will also suffice to describe how the nitrous vitriol is conveyed from the cistern, *b*, into the cistern, *c*. It will be seen that from the bottom of the cistern, *b*, a short tube proceeds, which immediately joins on to the main pipe or artery, *f*; into the conical mouth of this pipe which opens into the cistern, a plug is fixed, which plug, like the one already described, is simply a conical boss or mass of lead cast on to the end of a sufficiently long rod of iron, and turned in a lathe to a fine surface, so as to make as accurate a fit as possible, the shank being sheathed in lead so as to preserve it. The upper end of this rod is split, so as to embrace a lever, to which it is firmly attached by a hinge-like joint. This will be better understood by referring to Fig. 586, where *a* is the plug, as already described; *b* is the lever to which it is attached; *c* is a joint at one end of the lever, and which serves as a fulcrum; *d* is the handle at the other end of the lever; *e* is a guide in which it works, and which confines its movements to a simple vertical motion. The plug apparatus is fixed, as shown in Fig. 586, across the corner of the cistern. Now, to get the vitriol in *b*—Fig. 582—into the iron vessel, the workman simply lifts the plug at the corner of the cistern; this he does by a sudden jerk, after loosening a little piece of apparatus, to be hereafter described, and which is for the purpose of keeping the plug in its place and preventing its rising when the pressure comes on to its under surface. Immediately he lifts this plug the sulphuric acid proceeds to run down this short tube into the main artery, and thence into the cylinder, driving out the air through a tap placed for the purpose. Immediately the cistern is empty, the workman by a forcible thrust fixes the plug in its seat, and for fear the pressure should force it out, he proceeds to fasten it down, as shown at the cistern, *b*—in Fig. 582—where in the upright, *h*, a number of holes are shown; into one of these a *cotter*, or piece of round rod iron, is thrust; then between this cotter and the lever he drives in the wedge, *i*, thus effectually preventing the rise of the lever, and consequently firmly holding the plug in its place. As soon as this is accomplished, he proceeds to set the air-pump in action, which air-pump injects air on to the surface of the vitriol; and when sufficient pressure has accumulated, the acid gradually flows along the horizontal pipe and main artery, *f*, until it arrives at the pipe, *f*, along which it proceeds, eventually emptying itself into the cistern, *c*, the air-pump being kept in action until all the vitriol is forced out of the cylinder, and a small portion of air following indicates when this has taken place.

Fig. 586.



The next part of the process is the conveyance of raw vitriol into the cistern, *c*. The details are precisely similar to those already described. Let the reader imagine another cistern precisely like cistern *b*, a perfect copy plug included, which said cistern has a short plug connecting it with the main pipe or artery, *f*. As in the case of cistern *b*, the workman removes the plug, and allows the vitriol to flow into the iron cylinder as before; when he has done this he proceeds to take measures for projecting this charge into the cistern, *a*, at the top of the column.

On the branch pipe leading to the nitrous vitriol reserve cistern, *c*, a plug apparatus will be observed. This is for the purpose of closing this branch pipe while raising the raw vitriol, and is taken out when the nitrous vitriol is being pumped up. It is scarcely necessary to remark that when the nitrous vitriol flows through this branch pipe, it naturally issues at the open end over the cistern, *c*, such being the lowest. In order to prevent the raw vitriol taking the same course, the workman firmly inserts and fastens down this plug, and, when the acid to be used for absorption has filled the iron vessel, he sets the air-pump in motion, and the vitriol rises up to and flows into cistern *a*.

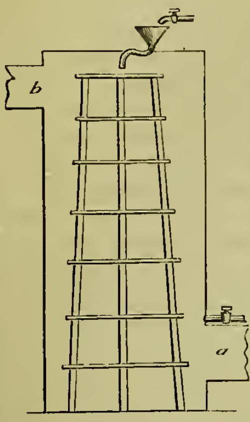
In consequence of the height of the column of liquid rising from the bottom of the iron vessel to the upper edge of the cistern, *a*—a space of nearly thirty-eight feet—and of its superior gravity, a pressure is exerted approaching to thirty pounds on the square inch. Hence it will be apparent that the cylinder and its appendages must possess a considerable amount of strength. It is usual to have them cast two inches thick in the sides in order to withstand this weight.

The air-pump used in this case, and which has been so often mentioned, is constructed on the model of an iron furnace-blowing engine, and differs from it only in dimension. The cylinder of this pump may be about eight inches diameter, the length of stroke being twelve inches, and it makes about fifty strokes per minute. It has a rather heavy fly wheel attached to it, to steady its action. This is necessary on account of the great resistance it has to overcome at the end of each stroke. It is necessary that the piston should fit very accurately, and that about the pump and the fittings generally great care should be taken to insure perfect freedom from leakage.

The quantity of sulphuric acid used in the absorption is rather variable, some manufacturers being more successful in this respect than others. Many who employ this apparatus recommend one-third of the make to be run down every twenty-four hours. In this case, for every hundred tons of acid made per week, nearly five tons would be run down per diem. One manufacturer finds in practice that about four hundred gallons, or seven thousand pounds, run down the column every twelve hours, will absorb the nitrous gas from a set of chambers which are converting eighteen tons of sulphur weekly into sulphuric acid.

To utilize the nitrous vitriol it is necessary to liberate the nitrous acid it holds, either within the chamber or contiguous to it, and in presence of the sulphurous and other gases entering it. Simple dilution with water effects this, as explained at page 1033. Still its practical working at first was found somewhat difficult, and much ingenuity has been expended in improving this part of the process, but still something further remains to be done before it can be considered perfect. The original inventor gave a method which, though theoretically almost perfect, was, unfortunately, not quite so, practically. It consisted in exposing the nitrous sulphuric acid in thin films or sheets to the action of the sulphurous acid which issued from the sulphur ovens. By this he proposed to liberate the nitrous gas, and in part he did so. The apparatus is shown in Fig. 587, which represents a sort of leaden column. Within this column a series of horizontal shelves or partitions are placed, which almost fill up the whole of the area; a funnel, furnished with an S tube, is inserted into the roof, and through this the nitrous sulphuric acid is poured on to the shelf immediately beneath. It runs from this first shelf on to the next one, and so it proceeds to the bottom, in exactly an opposite direction to that pursued by the sulphurous acid current, fresh portions of which it meets at every point of its progress downwards. The funnel tube is of an S form, for the purpose of preventing any of the gas escaping, a quantity of the liquid being retained in the curvature of the tube sufficient to prevent effectually the loss of any gas.

Fig. 587.



The sulphurous acid is admitted into this column through the wide tube at *a*, while immediately above this a jet of steam is thrown in; these together, after traversing the spaces between the shelves and acting on the downward stream, finally escape laden with nitrous gas into the chamber through the passage, *b*.

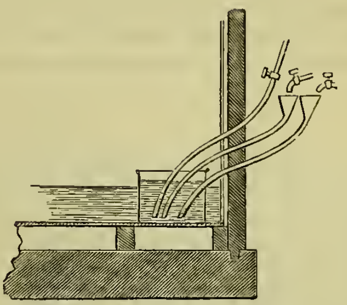
The jet of steam just mentioned is for the purpose of diluting the nitrous sulphuric acid, and so causing it to yield up more readily the nitrous gas.

The acid, by the time it reaches the bottom, is supposed to be thoroughly denitrated, and is conducted thence to an evaporating pan to be concentrated, in order that it may be once more used for the absorption of a fresh portion of gas in the absorbing column. Theoretically considered, the nitrous vitriol ought to run from the lower portion of the apparatus without containing more than a trace of any nitrous body. On the contrary, it might be expected to be charged with sulphurous acid, but practically this does not appear to have been the case; for, from the statement of those who had ample opportunity of examining its action, it appears that the nitrous constituent was never thoroughly eliminated, that it still retained a considerable quantity of this gas after very slowly traversing the apparatus, and that this impossibility of thoroughly decomposing the compound acted as a strong barrier to the introduction of the invention. But, happily, this defect was not unconquerable, and was, by a reasonable amount of skill and patience, eventually obviated, at least practically so, if not perfectly.

The nitrous sulphuric acid is decomposed, but comparatively slowly, when subjected to the action of sulphurous acid in an undiluted state; and this appears to have been the cause of the failure in the commencement, inasmuch as the acid flowed from the decomposer almost of the same density as when introduced. It would seem inconsistent that the expedient of mixing it with water so as to dilute it was not adopted, especially as the decomposing action of water *per se* must have been observed. Doubtless this would have solved the problem, especially as with this addition a modification of his apparatus answers very well.

The mere dilution of this nitrous sulphuric acid with hot water answers very well. This is done within the chamber. A section of the apparatus employed is shown in Fig. 588. It consists in simply placing within the chamber, and as near the burner stalk as possible, a round leaden vessel about twelve inches high and eighteen inches diameter. This is placed close to the leaden wall of the chamber. This leaden wall is pierced by three tubes, all terminating within the leaden vessel, and near to its bottom. One of these tubes conveys the nitrous sulphuric acid into the vessel; the second conveys water; and the third is a steam-pipe. The two tubes for the liquids terminate on the outside of the chamber in funnels, while above these funnels are the respective taps, one of which communicates with the nitrous vitriol-store cistern, and the other with the supply of water. The steam-pipe is, of course, in connection with a generator.

Fig. 588.



Supposing the chamber to be at work, the mode of operating, with this arrangement, is very simple. The leaden box or vessel is first run full of water—this is by means of the steam jet brought to boiling. The operator or workman then proceeds to run in a slow stream of nitrous vitriol and water from their respective taps. Immediately the nitrous vitriol touches the hot water below, it decomposes into sulphuric acid simply, —which remains in the vessel for a while—and nitrous gas, which flies off, and which is, by the current of gas ascending from the burner, carried off, and enters into the working of the chamber.

Of course, the vessel always remains as near as possible full. The streams of fresh liquid running in immediately displace and drive out a portion of the previous contents, causing it to mix with that already contained in the chamber.

There are at least two advantages which arise from placing this decomposer as near the burner-pipe or gas tubes as possible. In the first place, the gas arising from the decomposition has a better chance of thoroughly mixing with the rest of the gases which form the chamber mixture; and, in the next place, this rapid removal and immediate mixture lessens the risk of local action on the chamber, nitrous gas being rather destructive to lead. In fact, the rapid current of sulphurous acid gas must sweep away every particle of nitrous gas as fast as it is liberated. One of these decomposers has been working in a chamber for nearly three years, and the lead in its immediate neighborhood does not appear to have suffered more than that in any other part of the chamber.

Mr. PETER HART of Manchester has given a method of estimating the value of this nitrous vitriol by a process of analysis by which one may, in a very simple manner, determine how much nitrate of soda or nitric acid a given volume of this nitrous vitriol represents, or is equal to. The process is founded on the well known reaction which takes place on bringing nitrous acid and urea together, the result of this proceeding being the formation of water, nitrogen, and carbonic acid gases, as shown in the following formulæ—

$$\underbrace{C_2\,N_2\,H_4\,O_2}_{\text{Urea.}} + \underbrace{2\,NO_3}_{\text{Nitrous acid}} = \underbrace{2\,CO_2}_{\text{Carbonic acid.}} + \underbrace{4\,N}_{\text{Nitrogen.}} + \underbrace{4\,HO.}_{\text{Water.}}$$

Mr. HART prefers to employ urea, in the shape of nitrate, on account of the facility with which it can be obtained pure. Of this nitrate of urea he weighs out twenty grains, and dissolves this in about two and a half ounces of water, heating this solution to boiling over a gas lamp. Meanwhile he prepares a test liquid, composed of thin starch water, in which he dissolves a small quantity of iodide of potassium. He spots a white plate with drops of this liquid. He then fills up an ordinary alkalimeter with the nitrous vitriol to be tested. Meanwhile the solution of urea has arrived at boiling, at which point he lowers the gas flame, and proceeds to add the nitrous vitriol from the alkalimeter to the solution in the basin. The reaction goes forward with strong effervescence, and escape of nitrogen and carbonic acid gases. He continues to add the nitrous vitriol drop by drop, not neglecting to stir until a drop, taken out of the basin by means of a glass rod, and added to one of the test spots on the plate, causes the latter to assume a blue color. This indicates the completion of the operation. The number of measures used or added are read off, and this forms the data for the calculation. The rationale of the process is very simple. After the decomposition of all the urea, the nitrous acid, which hitherto has been simultaneously decomposed with the urea, now remains in a free state. Now, it is well known that nitrous acid decomposes hydriodic acid, setting iodine free, which iodine will immediately combine with starch, if any be present. This is one of the tests for nitrous acid; so in this case the formation of the blue coloration indicates free nitrous acid in the basin; and free nitrous acid present indicates the decomposition of all the urea.

The calculation is based on the fact, that to decompose the twenty grains of nitrate of urea employed, there would be required 12·35 grains nitrous acid, NO_3, which is equivalent to, or represents in chamber effect, 17·56 grains nitric acid, NO_5, or 27·64 grains nitrate of soda; consequently the number of alkalimeter measures of the nitrous vitriol required in the decomposition represents or contains the equivalent of any of these numbers. All that remains to be done is, to ascertain the relation borne by this quantity to the volume which the cistern is capable of holding, or contains at the time of the experiment; or to put it as Mr. HART gives it—let a represent the number of alkalimeter measures employed of the nitrous vitriol; b the nitrate of soda—if the result is required in nitrate of soda—corresponding to the twenty grains of nitrate of urea, as given above; c the number of alkalimeter measures in a gallon—seven thousand—and d the number of gallons in the cistern; then—

$$\frac{b \times c}{a} \times d = x$$

x indicating the equivalent in nitrate of soda of the recovered nitrous acid in the entire cistern.

Another method of recovering the nitrous gas has been lately patented in this country. It differs very considerably from the one already described, that is, in principle, although the apparatus bears a great resemblance. It consists essentially in converting the nitrous gases into nitric acid, and combining this acid with lime. The inventor starts out with a column, as in the last process, filled with suitable materials to afford a large surface, down which he runs a stream of thin milk of lime, allowing the waste gases from the chamber to ascend in the opposite direction. In this case it is supposed that, under the influence of the alkaline fluid and excess of atmospheric oxygen, the oxides of nitrogen will be wholly converted into nitric acid, which will immediately combine with the lime, forming nitrate of lime.

It is well known that nitric acid can be reproduced from any of the lower oxides of nitrogen—with the exception of, perhaps, the lowest, nitrous oxide, NO, when in contact with water and free oxygen. This has been dilated upon, and the reaction given when treating of the chamber reaction; and that this is a fact there is no doubt. The only difficulty hitherto appears to have been to obtain nitric acid of a suitable strength. This has scarcely been accomplished, as experiments have shown that the reaction proceeds with less rapidity as the acid gains density. But where lime-water is used this objection is removed, inasmuch as no free acid can exist in the liquid to retard the reaction; each atom of this acid being removed or combined at the moment of its formation, or immediately afterwards. There is no doubt that the presence of an alkali not only obviates this retardation, but actually induces, by its presence, the combination of the lower oxides of nitrogen with oxygen, thus, in fact, acting in a doubly advantageous manner.

The solution of nitrate of lime, formed in the column, is run into a proper cistern placed for its reception and conservation prior to its being converted into a dry or crystalline salt, which the inventor proposes to employ instead of nitrate of soda, as a constituent of the artificial manures now so much in request.

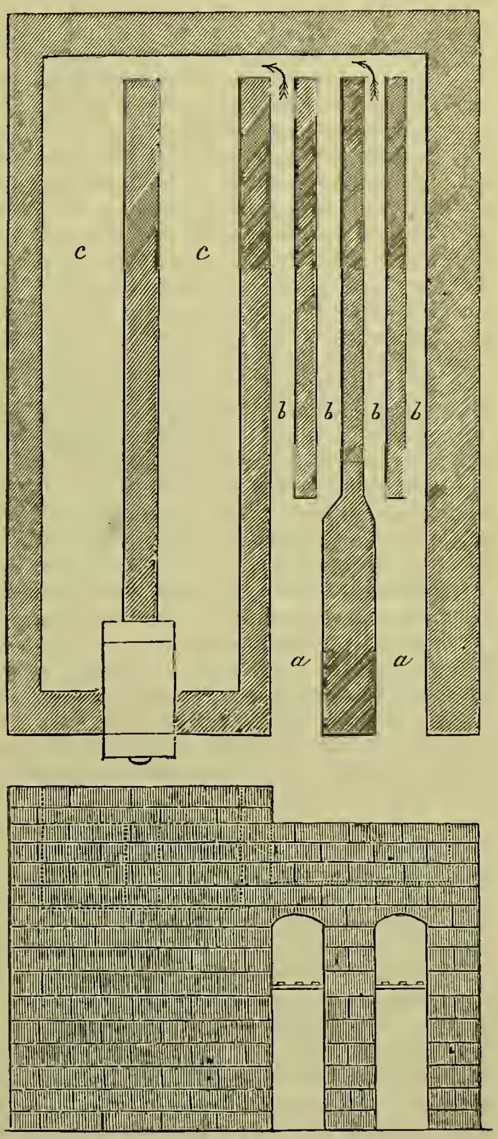
Perhaps the process would have been more perfect had it been more self-containing, and not dependent on outer circumstances for its perfect well-doing; that is, if the vitriol manufacturer, instead of having to depend on the purchase of this nitrate by other parties, could have used it himself. Were it cheaply decomposable, that is to say, were it possible to eliminate the nitric acid cheaply, it would be better; but it can only be decomposed with ease by the addition of some stronger acid, and the only one reasonably available for this purpose is sulphuric acid. By substituting this nitrate of lime for the nitrate of soda or potassa, ordinarily employed, one would certainly most effectually get back the nitric acid; but, unfortunately, sulphate of lime, a body of no value, would be produced, instead of, as now, producing sulphate of soda or potassa, salts in great and constant demand.

Of the value of processes for the recovery of the nitrous gas little need be said. The benefits they confer are apparent at once, recovering, as they do, the most expensive element in the manufacture, and not only being a saving of the money value of the nitre or its equivalent recovered, but further, when looked at in a politico-economical point of view, another phase presents itself: for were all sulphuric acid manufacturers able to work with half the nitrate they at present use, it would surely tend to reduce the price of this salt; and, if the maxim be correct, that price is regulated by supply and demand, then under the imaginary state of things just mentioned, one-half the quantity now used being thrown on the market, or what is the same thing, not used, must bring down the price of what could be sold, thus lowering a second time the cost of manufacturing sulphuric acid.

Concentration of Sulphuric Acid.—Sulphuric acid, as it exists in the chambers, though strong enough for many purposes, is not sufficiently so for sale, inasmuch as it is the object of the manufacturer to send it out as strong as conveniently may be, in order to avoid the necessity of conveying a quantity of useless water. It is concentrated up to a certain point in leaden pans; that is, until it has attained the density of 1·750; beyond this point it is not considered safe to push the concentration in lead. In order to bring it up to its maximum degree of concentration, or its conversion into what is termed rectified oil of vitriol, the extrication of the further remaining quantity of water must be performed in vessels of glass or platinum.

With respect to its concentration in lead a variety of plans are in use for this purpose. Much difference of opinion exists on this head amongst sulphuric acid manufacturers; their choice probably depending on convenience and situation. One manufacturer, for instance, prefers to concentrate his vitriol by passing the flame and products of combustion of a fire over the surface of his weak acid, the watery vapor being carried away with the smoke, *et cetera.* This plan appears to answer very well where no niceness with respect to the color and purity of the acid is demanded—as when the vitriol manufacturer is also a soda manufacturer, and uses up his own acid; but as the concentrated acid resulting from this mode of working is almost invariably very black and turbid in consequence of particles of coal-dust, *et cetera*, falling into the hot liquid, as well as from contact with the various carbonaceous bodies forming coal smoke, such acid would be scarcely saleable in the ordinary way to calico-printers, bleachers, and other such consumers. In order to avoid this, the manufacturer must employ an apparatus in which the liquid is kept clear from all or any such contaminations. For this purpose a pan in principle, though not in shape, resembling an ordinary pan or boiler, must be employed. This variety of concentrating boiler is in very general use, being, in fact, almost universal amongst those manufacturers who sell their acid; whilst the surface concentrator is as commonly employed amongst the soda manufacturers and others, who make the acid solely for their own use.

Fig. 589.



The following describes the plan of a manufacturer who makes for sale only. This plan is found to answer very well; it consists of two pans, placed side by side, one being placed higher than the other—so high that its contents can be emptied completely by means of a siphon into the lower pan. No joinings or solderings of any kind are admissible about these pans, the whole must be formed out of one solid sheet of lead, the sides and ends being turned up simply: the lead is half an inch thick, the other dimensions of the sheet being thirty-three feet by seven feet six inches. To form such a pan, the sheet of lead is first spread out on the bed prepared to receive it; the plumber proceeds to mark off eighteen inches from each side of the sheet; this is to form the sides and ends of the pan. To facilitate the bending, a fire of shavings is made along the line of markings. When the lead has become sufficiently hot along these lines, he proceeds to bend up the sides, and to beat out any inequalities. The brick-work setting of the pans will be understood from the preceding figures, in which Fig. 589 represents the arrangement of the flues, previous to being covered in with the fire-tiles or iron plates on which the bottom of the pan is to be placed; the left hand portion represents the bed of the lower pan, while to the right we have that of the upper one. *a a* are the two fire-places, the flame from which proceeds along the narrow flues or passages, *b b b b;* they turn off at the end in the direction of the arrows, and return beneath the upper pan, along the two wide flues, *c c*, and from thence pass into the wide flue leading to the chimney. Fig. 589 is a vertical section, lengthways, of the fireplace of the lower pan; *c* is the course of thick fire-tiles immediately over the fire, protecting the pan from the too great heat; a little beyond the fire thinner tiles are employed, which thin tiles are continued to the end. The two wide passages, *cc*—Fig. 589—beneath the upper pan are covered with iron plates, half an inch thick, on which the pan is placed. It will be understood from this description, that the tiles, or other supporting medium, diminishes in thickness, but increases in conducting power as the distance from the fire increases. This arrangement is necessary, for were iron plates used the whole distance, they would soon be burned through and destroyed in the immediate neighborhood of the fire; and, on the contrary, were thick tiles used for the whole distance, the latter portion of the arrangement near the end of the pan would offer too much resistance to the passage of the heat, and consequently a considerable portion would pass away without being absorbed.

Two such pans are capable of concentrating the acid produced from eight tons of sulphur per week of six days. There are pans at present in use capable of concentrating forty tons of vitriol weekly. Their mode of working is as follows:—The vitriol in the lower pan being of the proper strength, the workman proceeds to run it off into a vessel called a cooler, where it remains until cold. He runs it empty to within two or three inches; when this is accomplished, he proceeds to set a siphon into the upper pan, running the contents into the lower one, which lower one he fills within two or three inches of the top. When the upper pan is empty he refills it with the weak acid from the chamber; he then proceeds to fire the pan until next day, when he will repeat the operations just described.

The other description of pan, the one spoken of as a surface concentrator, is of the following description: Fig. 590 being a vertical section lengthways, the fire-place is at *a*, the flame, *et cetera*, proceeding in the direction of the arrows over the surface of the dilute acid at *b*, when it descends into the flue, carrying with it the evaporated water. It resembles—with the exception of some particular details, to suit the material to be evaporated—the furnace described under the head ALUM in this work, Fig. 89; but in the case of sulphuric acid, the furnace has to be lined, so to speak, with lead; and this lead being liable to fuse at a comparatively low temperature, much ingenuity is displayed in the methods adopted to prevent as much as possible such an occurrence. One mode of accomplishing this is shown in Fig. 590, where *d d* is a section of the leaden pan, inclosed in brickwork, to prevent the action of the flame. The side of the pan is brought up to the furnace dam, *e*; then within the pan a close row of firebricks, *b*, are placed on end, but not cemented in any way. Thus the sides of the pan are inclosed between brick walls, it only remains to cover up the space, and this is done by placing firebricks on the top, resting partly on the furnace dam, and partly on the row of bricks just mentioned; the flame is thus completely kept off the lead. This is repeated all round, the pan's sides and ends being equally protected. Some manufacturers employ a slightly different arrangement, although on the same principle. A covering brick, expressly made for the purpose, is employed; these bricks are made of the proper size, with an indentation or channel formed in them; this channel being for the purpose of inclosing the upper edge of the pan, side or end. This arrangement is shown in Fig. 591, where *a* is the pan edge; *b*, the brick or tile, with its channel, *c*, inclosing the edge of the pan.

Fig. 590.

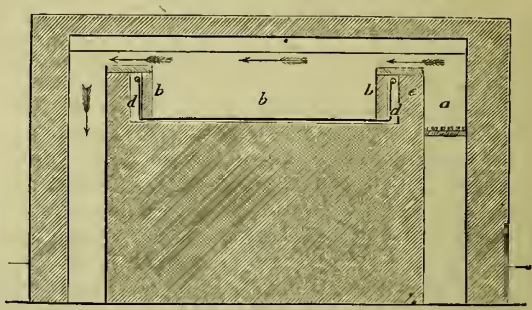
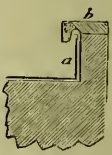


Fig. 591.



Though these precautions would appear to be sufficient, yet the manufacturer usually avails himself of another invention, which consists in running a stream of cold water round the pan's edge. This is effected by burning or fusing—by means of the hydrogen apparatus mentioned in another portion of this article—to the edge of the pan a leaden tube of a D shape, the flat side being next to the pan; a section of this pipe is shown in Figs. 590 and 591. This arrangement has a current of cold water constantly flowing through it.

These vitriol pans are often of immense thickness, in some cases the lead of which they are made is an inch thick; but as the heat does not, as in the previously described pans, penetrate through this, it is immaterial. They are worked rather differently to the other pans, inasmuch as it is necessary to cool them to a much lower temperature before running them off. Before this is done the fire must be slackened, or rather put out; for, were the pan to be emptied while the fire was burning with its usual vigor, the pan sides might get so hot as to become soft, and fall or bend down. The upper portion is an arch of firebrick, through which a hole is pierced over one corner of the pan;

through this hole the siphon is inserted for drawing off the finished vitriol; it is also refilled with dilute acid through this. The workman ascertains the progress of the concentration, or its completion, in all cases by taking out a portion from time to time, and placing the vessel containing this trial sample in water to cool. When cold enough, he ascertains the density by means of the hydrometer. When finished it must, as before stated, be of the density of 1·750, or of the strength of 150° on TWADDELL'S hydrometer—the instrument most used in this country—when at a temperature of 60°. When of this density, he draws out the fire and proceeds to run the vitriol into what are called coolers, which, as their name indicates, are for the purpose of holding the acid until sufficiently cool to run off into the glass bottles called carboys, for sale or transport to its destination.

These coolers, which are simply shallow lead vessels almost identical with the first-described pans, are, like the latter, formed out of an entire sheet of lead, sometimes half-inch, often of quarter-inch thick. This is, of course, an indifferent matter. The half-inch will last much longer, nevertheless it is not advisable to make them of less than quarter-inch. These coolers are set on iron plates in the manner described with reference to the upper pan; but the ends of the flues are open to the air, which, circulating through these passages, carries off the heat. The sides and ends are held up by brick walls or other convenient supports.

Very good and efficient coolers are constructed as follows:—The dimensions of an iron vessel, capable of holding the quantity of vitriol likely to be run off from the pan, are calculated—these parts are cast of about half-inch thick iron in such a manner that the whole can be securely bolted together. No care is requisite with respect to the accurate fitting of the various joints, as the whole must be lined with say quarter-inch lead. This lead must be turned over the upper edge and flattened down so as to prevent any infiltration of acid between the iron and the lead. If this is not attended to, the acid which finds its way down will act upon the iron, producing protosulphate of iron in masses. These will continue to grow in size, and in so doing will push the lead from the iron, producing misshapen prominences, which will finally destroy the cooler, or rather necessitate the removal of the lead lining, the cleaning the surface of the iron, and finally relining with lead. Two of these coolers, of six feet square and two feet deep, have been in use for some time; they cool the vitriol very rapidly. They are not set on the floor, but on two low walls of brick, so that almost the whole surface of the iron is exposed to the cooling influence of the atmosphere, and the heat is quickly carried off.

It is possible to construct coolers by simply lining a wooden cistern with lead: such are used for crystallizing various salts; but it is a question whether they can be recommended, inasmuch as the cooling must be very slow, on account of the bad conducting quality of the wood which forms the coating to the lead.

In most vitriol works two coolers are used in connection with the pan or pans. Suppose they are called No. 1 and No. 2, the mode of working resembles that of the pans first described; that is, No. 1 is supposed to be cool enough to bear bottling. When this is done, the contents of the upper cooler, or No. 2, is now run into No. 1, while No. 2 is now ready to receive a fresh quantity from the lower concentrating pan. It will thus be seen that in working a set of concentrating pans and their accompaniments, four stages may be recognized. The upper pan partially concentrates the acid ready for the lower pan, which then completes the concentration. From this lower pan it is run into the upper cooler, where it loses the greater portion of its heat, and finally it is run into the lower cooler, where it remains until quite cold or nearly so.

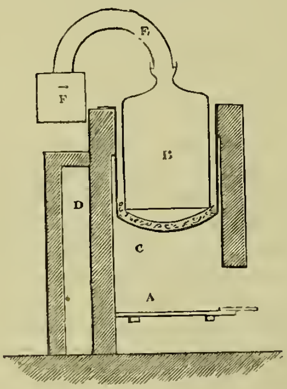
The system just described is in constant use in some works, but is not by any means universal, each manufacturer limiting the extent of his apparatus to his wants. The arrangement most usually seen, especially in small works, is a single boiling-down pan, as it is technically termed; the heat passing beneath it up one flue and returning to the same end down another, after which it passes to the chimney. This pan is accompanied by one cooler. The raw acid from the chamber is run into this single pan, where it is concentrated up to the proper point, after which it is run into the cooler, where it stays until cold; and if the pan is ready to run off again before the vitriol in the cooler is cold enough, there is no help for it, but drawing the fires and letting it stay in the pan until it can be accommodated.

There is no objection to this system except, perhaps, that it is not calculated to do much work; still it answers sufficiently well for small manufacturers.

The manufacture of sulphuric acid has now been traced to the completion of a commercial product, which, in the language of the trade, is called brown oil of vitriol, in order to distinguish it from a product of still higher concentration, to be immediately described. This brown oil of vitriol is used to a large extent by bleachers, calico-printers, dyers, and others; its brown color, from which it derives its name, is due to a certain amount of organic matter which finds its way into it, and which, subjected to the joint action of the acid and heat, becomes carbonized, and colors the whole of a dingy-brown hue. This tint is often augmented from accidental circumstances. Sometimes the workman lets the rag or paper protector, with which he covers his hand while setting the siphon, drop into the pan, at other times fragments of wood-shavings or sawdust find their way into it; when this is the case the vitriol well deserves its name of brown; perhaps, under these circumstances, black would more nearly designate its color. When such an accident occurs, it is usual to destroy this black or brown color by sprinkling a small quantity of some highly oxidizing body into the vitriol while hot in the pan; either nitrate of potassa or soda answers well for this purpose. Finely powdered black oxide of manganese may be used. These bodies yield up sufficient oxygen to the black matter to destroy it, or convert it into some colorless body which does not offend the eye.

Monohydrated Sulphuric Acid—Rectified Oil of Vitriol—English Oil of Vitriol.—Brown oil of vitriol is not sufficiently strong for several purposes; amongst others may be enumerated the manufacture of the dyeing compound known in commerce as extract of indigo, sometimes called sulphate of indigo. Fuming Nordhausen acid is often directed to be employed in the formation of this body, but in this country it is usual to employ the strongest English sulphuric acid. In order to procure this acid the following methods are adopted:—It has been stated previously that the concentration cannot be safely conducted in lead beyond the density of 1·750, for if driven further, not only would the metal be rather strongly acted upon, but there would be considerable risk of the pan-sides falling in, in consequence of the softening of the lead; so high would the degree of heat become before the last portion of water could be driven off. The further concentration, then, must be performed in vessels made of a material which will withstand the corrosive action of the boiling acid, and which is comparatively infusible. Glass at once suggests itself or some variety of earthenware, such as porcelain, or, amongst the metals, platinum or gold. Of the former two glass offers most advantages, and of the two latter materials platinum is preferable, inasmuch as it resists acids quite as well, and is much cheaper than gold. Glass has been employed in the concentration of vitriol from very early times, perhaps from the period when sulphuric acid began to be understood, and its manufacture attempted on a very small scale, doubtless before the introduction of leaden pans. Platinum, on the other hand, is a comparatively late introduction. The glass vessels employed in the last concentration of sulphuric acid, or, as they are technically known, retorts, resemble very much the bottles or carboys used to transport vitriol from place to place. Their figure is shown in section in Fig. 592, which represents the whole arrangement when at work.

Fig. 592.

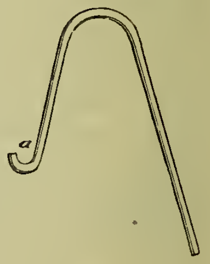


These retorts vary some little in size, manufacturers having lately begun to use much larger ones than were formerly employed. Those in use at the present day are capable of holding more than twenty gallons of liquid, inasmuch as after the rectification or concentration there remains in the retort sufficient vitriol to fill two carboys. This is equal to twenty gallons.

The mode of working can be gathered from the drawing, where A represents the fireplace; the flame, *et cetera*, from the fire plays round the cast-iron pot, C, finally making its exit into the flue, D. On the bottom of the iron pot just mentioned a quantity of dry sand is laid; and on this the retort, B, is placed, the sand serving as a steady support for it. The retort is not, as is sometimes supposed, surrounded with sand; for, if this were done, it would run some risk of being broken, besides materially retarding the cooling when the rectification was over.

The retort being placed, as in the drawing, it is filled with cold brown vitriol; and when this is done the fire is lighted; the arm, E, is put into its place; the apparatus gradually warms up, and eventually the acid boils; water, with a little sulphuric acid, distils off. This vapor passes off by the stoneware arm, E, into the leaden draught-pipe, F, where a quantity of it condenses; but the greater portion finds its way from thence into the chimney. The contents of the retort are kept boiling for some hours, or until the brown color entirely disappears; for this appears to be the only reaction by which to determine the conclusion of the rectification. It would appear that the organic matter resists the destroying or oxidizing action of the acid, until it has reached its highest point of concentration and temperature. When the clearing has taken place, the fire is withdrawn from beneath the pot; and the whole arrangement is allowed to cool down to a safe temperature, when it is drawn off into carboys. This drawing off is effected by a peculiar siphon, being in fact what is known as MITSCHERLICH'S siphon; but in this case, on a rather large scale, as shown in Fig. 593, it consists of a siphon, with the shorter of its two legs turned back upon itself, as shown at *a*. This turned-up portion should be as short and as close to the siphon leg as possible, in order to be the more easily inserted into the neck of the retort; it is rather exaggerated in the drawing. In order to withdraw the concentrated acid from the retort, the workman first removes the earthenware arm; the siphon is filled with water, the man keeping his thumb firmly closed over the orifice of the longer leg. The shorter leg is inserted into the retort, and gently placed on the bottom; the workman then removes his thumb for a few seconds, until the acid has driven before it the water with which the siphon was charged; when this is done, the end is directed into a carboy which has been placed in readiness by an assistant. When the carboy is full the orifice is again closed by the thumb, while the full carboy is removed and replaced by another empty one. The whole range of retorts are emptied in this manner.

Fig. 593.

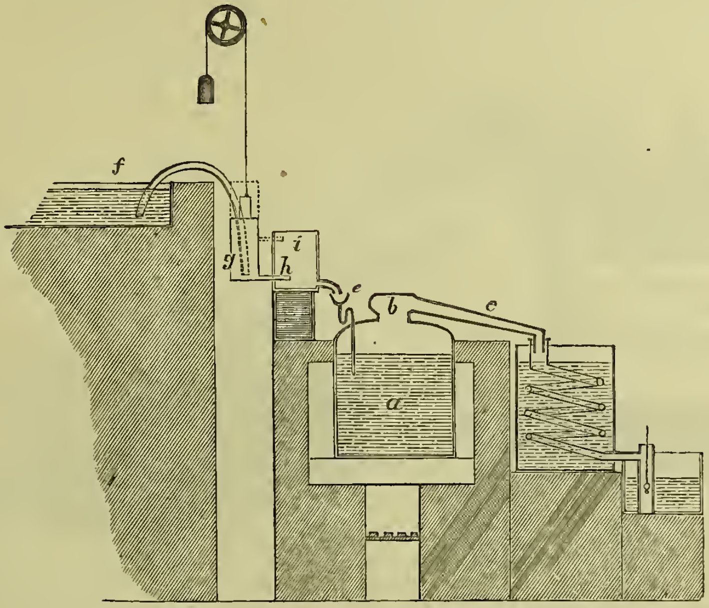


This product is the strongest English sulphuric acid; it is colorless or nearly so, and is of the density 1·850, or 170° on TWADDELL'S hydrometer.

When treating of the commencement of this process, the retort was directed to be filled with cold brown oil of vitriol; it was supposed in this case that the retort was newly starting; but as one charge is now supposed to have been worked off, it will be more or less warm, and the introduction of cold vitriol at this juncture might possibly fracture it. Therefore, it will be necessary to recharge it with warm vitriol, or with vitriol as nearly the same temperature as the retort as possible; and this must be made a rule, if annoyance would be avoided.

It is usual to find in books treating of this matter, the apparatus for rectifying in glass described as consisting of a great number of the retorts, with their accompanying sandpots, *et cetera*, set in a battery, that is, a number of them heated by one fire. Though this may have been the case at one time, it is not the practice or custom to operate in this manner at the present day. Such an arrangement could not have worked as well as the present one, the probabilities being that the retorts which were placed nearest the source of heat, would arrive at their maximum point of concentration some time before those at the end of the arrangement furthest from the fire were finished; in such a case it would have been necessary to have kept on firing until the whole set were done. The result would be that a considerable quantity of sulphuric acid would have distilled off the finished retorts, while those in the rear were being finished. In the present arrangement each retort is by itself, has its own fire, and consequently works totally independent of its neighbors.

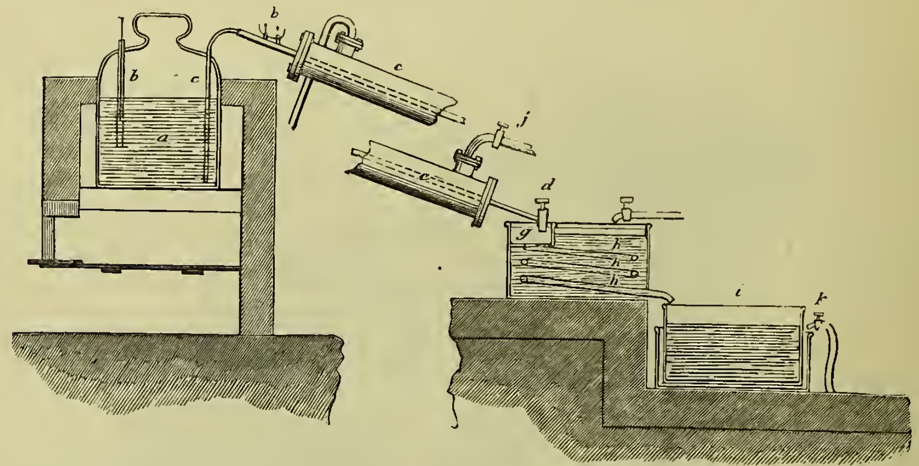
Fig. 594.



The defect of this system of operating is the great fragility of the operating vessel, and the consequent liability to fracture either from a blow or other accident of the kind, or from change of temperature. The room or shed in which a concentrating plant of this description is working, should be closed, and every precaution taken to prevent the access of draughts of cold air or other cooling influence. It is no uncommon occurrence for two or three retorts to be cracked round the top, from the sudden rush of cold wind through an opened door, in such a manner that the whole upper part of the retort could be lifted off; the crack having gone completely round it, and severed the upper portion as completely and as straight along the protecting edge of the sandpot, as though it had been done with a diamond. Mr. Jones of Bristol took out a patent in the year 1845, for a protector to obviate this accident. The protector consisted of a sort of sheet-iron bell-jar, if such a term may be used; this bell-jar has a hole cut in the upper portion, so that the whole may be placed over a retort when in work, the neck of the retort protruding through this orifice, while the lower edge of this cover rested on the upper edge of the sand-pot. Such an arrangement effectually protects this part of the retorts from cold draughts, or drops of cold liquid, which, as may be easily imagined, are equally destructive. In fact, any cool or cold body coming in contact with the heated glass is fatal to it, causing much inconvenience; for not only is the retort itself destroyed, but the contents are lost, also creating the greatest annoyance and discomfort, for the vitriol trickles or runs out, and, coming in contact with the red-hot pot, is converted into vapor of a most suffocating kind, filling the whole place. This calamity is without remedy; and even though a remedy were to present itself, it would be impossible to enter the place, and apply it, without running considerable risk of suffocation.

These risks and drawbacks were doubtless the stimulants which brought out the platinum retort, this costly, but efficient substitute being safe from the casualties just described. This retort, with its appendages, is shown in Figs. 594 and 595. The former is a vertical section in front; *a*, is the body of the retort; *b*, the head; *c*, a platinum tube leading from the head to a leaden worm, which worm is kept immersed in water; *e* is a platinum funnel, the tube of which is S-shaped, to prevent the return of any vapor. The brown acid which is kept in the cistern, *f*, under which the waste heat passes, is run into the body of the retort without the aid of any tap or valve by means of the at-first sight rather complicated, but really simple apparatus shown in the figure, where *g* represents a round vessel in which a tube, *h*, is inserted very near to the bottom; *i* is another leaden vessel, which has a slit in the side from the top nearly to the bottom, along which slit the tube, *h*, slides, when the vessel, *g*, is moved up or down by means of the chain and pulley. A siphon, which is kept constantly set, connects the stock cistern, *f*, with the vessel, *g*. The apparatus, when in the inactive state, as represented by the dotted lines, is as follows:—The siphon is full of vitriol, but the surface of the acid in the cistern being on a level with that in vessel *g*, no flow can take place; when the vessel, *g*, is lowered, the levels become altered; and as the leg of the siphon, which is in vessel *g*, becomes the longer, the acid begins to run into this vessel, and from this into vessel *i*, and thence into the funnel.

Fig. 595.



The other portions of the apparatus being at the back, are shown in Fig. 594, which is a side view; *a*, as before, is the body of the retort; *b*, is a platinum tube about three-fourths of an inch in diameter, in which a glass float is placed to indicate the depth of liquid in the still; *c*, is a siphon, also of platinum, of the same diameter as the tube just mentioned. This siphon is inclosed in an iron tube, *d*; between these two tubes a current of water can be passed. The siphon terminates in a platinum tap at *d*. The body of the still rests on a circular tile of refractory clay; the fire being below this tile, the flame rises at the back of the still, circulates round the sides, and finally passes from thence under the stock-pan. The course is shown in Fig. 595.

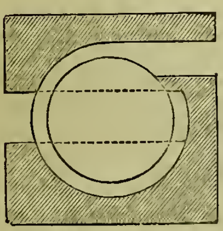
The mode of working this still is as follows:—The workman fills up his still a few inches above the highest point the flame is likely to reach; the fire is lighted and kept on until the contents are brought to boiling. The concentration then commences; vapor passes off through the head and conducting tube into the worm, where it again resumes the liquid form, running out into a vessel placed to receive it. This liquid is always acid, but at first it is very weak; it eventually reaches a density of 1·2400. When this strength is attained, the workman knows that the highest degree of concentration is arrived at. If the running-off siphon, *c*, is not set, he proceeds to do this by closing the tap, *d*. The two plugs are removed in the funnel, *f*, and the siphon is filled with vitriol; the plugs are replaced. It now only remains to open the tap, when the contents of the still begins to run off. The tap is allowed to remain open, until from three to four inches of the still contents are drawn. The workman is guided in this by the indications of the glass float before spoken of, which serves as a gauge. The acid falls into the cup, *g*, thence it flows through the serpentine coil of pipe, *h, h, h,* which is immersed in water; and finally it emerges still slightly warm at the end of the coil, and runs into the receiving vessel, *i*, which vessel stands within another one, a stream of cold water from the tap, *k*, circulating between the two. The water tap, *j*, is also turned, when running off, so that a stream of cold water cools the siphon itself. When the operation is over, the workman proceeds to repeat the course of operations just described; he fills up his still to its former level, attends to his fire, heats it up to the proper point, and again allows the acid to run off.

Such an apparatus, the still itself having a capacity of from seventy to eighty gallons, is capable of producing thirty carboys of rectified oil of vitriol in twelve hours, two carboys being all that a glass retort could produce in twenty hours; but this of course is owing to the latter requiring such a length of time to elapse before its contents can be safely drawn off. A retort of the above dimensions, with the siphon and float case, costs about fifteen hundred pounds, the price varying according to the thickness of metal, and consequently weight of platinum, yet it is generally admitted to be a more economical plan of operating than the glass retort system. But it is not free from disadvantages; it is necessary to be careful that the vitriol contains no nitrous compound, for if this be the case, the platinum is rapidly attacked. To obviate this, it is usual to add a quantity of sulphate of ammonia to the acid, while in the leaden concentrating pan, before it enters the still; the action of this salt is to decompose the nitrous body usually existing in vitriol. It is supposed that the following is the decomposition which takes place, assuming nitrous acid to be the body present:—

$$NH_3, SO_3 + NO_3 = SO_3 + 2\,N + 3\,HO.$$

This may occur in some cases, but it is not the invariable result. If a *little* sulphate of ammonia be dissolved in a small quantity of the nitrous vitriol of GAY-LUSSAC'S column, and the whole heated in a test tube, either NO_2 or NO_3 is evolved; nitrogen very probably is given off at the same time, but it is not the only body eliminated. When a rather large excess of sulphate of ammonia is employed, sulphide of hydrogen is formed in the still, and can be detected by the smell at the end of the condensing worm; undoubted evidence of its presence has been detected by means of lead paper. The only rule that can be laid down for guidance as to the quantity to be used, is the addition of an increased quantity of the salt each day until nitrous bodies cannot be detected in the finished vitriol; the workman at last obtains a good idea of the quantity to be added.

Fig. 596.

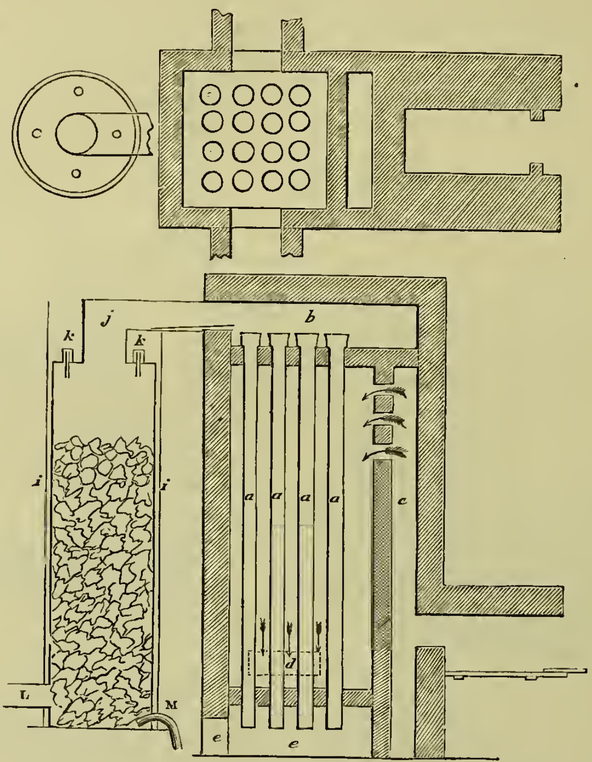


Sulphuric acid is brought to a saleable condition by the employment of one or other of the methods just described; but although these methods are universally employed, others have been proposed. The patentee who proposed to generate the steam necessary for the chamber by the combustion of the sulphur, also proposed to concentrate vitriol or any other liquid by means of the heat from this source, hitherto, in the inventor's opinion, wasted. The idea is very ingenious, perhaps more so than practical; but it would appear to be doubtful whether it is possible to concentrate vitriol at all by this process. The probability is that the sulphur would begin to sublime before the vitriol could be brought to the proper strength. The process is not in use in any part of the country, so that one may naturally infer that it is without practical value.

Perhaps the most ingenious proposal for the concentration of vitriol is the one about to be described, the prevailing principle of which is that of carrying over its surface streams of hot air, which, liberating and combining with the water, carries it off. The apparatus consists of two distinct portions, the one devoted to the production of highly heated air, and the other to the concentration. The former portion of the apparatus consists of a series of iron pipes, *a*—Fig. 597—set in brickwork; these tubes are heated externally by the flame of the furnace, *b*, the products of combustion from which pass up the space, *c*; they then descend and circulate round the tubes, finally making their exit into the main flue by means of the openings, *d*. The cold air from without enters the lower ends of the tubes which project into the arched recess, *e*, passes up them, and, becoming highly heated during its progress, enters the space, *f*, and passes along the wide iron tube, *g*, and thence into the concentrator. The portion of the apparatus devoted to the concentration is constructed entirely of lead; it consists of two concentric cylinders, *h*, *h*, made of half-inch lead; *i i*, is a small space, the use of which will be explained hereafter, which exists between them; both cylinders are closed at the bottom by being fused on to one sheet of lead; the inner cylinder is partially closed at the top, space only being left for joining on the leaden tube, *j*, which is a continuation of the iron tube, *g*, spoken of before, and is for the conveyance of the heated air. The inner column or cylinder is filled with coke, or other suitable material, which offers a large surface for the acid to spread itself over, at the same time being unattacked by it. The following is the method of working this apparatus:—The opening into the arched recess from which the cold air is drawn must be closed, or if there be a damper or register beyond the concentrator between it and the chimney, this must be pushed in. The furnace must be heated up until the pipes and the chamber containing them are of a good red heat. This state of preparation having been arrived at, the vitriol to be concentrated must be run on to the top of the inner cylinder; it runs down and fills up the space existing between the two cylinders, rising up to the mouths of and running down the tubes, *k*, *k*; these tubes are covered with lead caps, the bottom edge of these being immersed in the vitriol from an air-tight joint, which prevents any cold air being drawn in. The vitriol on flowing through these tubes spreads itself over the whole surface of the coke, wetting it thoroughly. When sufficient vitriol has been run in to saturate the whole of the coke, the hot-air current is allowed to enter it, penetrates every space and crevice in the mass, and heating the vitriol up to a high point, carries off its water finally when saturated, making its exit into the chimney by means of the wide tube or pipe, L. The vitriol becomes more and more concentrated, the nearer it approaches the lower part of the cylinder. When it has arrived at this point, if the amount of acid and hot air have been proportioned to each other, it will be found to be fully concentrated. It collects in a stratum at the bottom, until the surface rises sufficiently high to flow off into a proper reservoir or cistern through a bent tube, M. The use of the double cylinder has two advantages—it heats the sulphuric acid somewhat, previous to its admission into what may be called the concentrator proper; and also keeps the latter cool, or rather lessens the risk of its fusing if too great a heat should be employed.

The apparatus in the form just described, though capable of concentrating vitriol, cannot be said to be a success. The fusion of the lead in the upper portion was the weak point in this invention; in order to work the apparatus with practical efficiency, it was necessary to have the air highly heated, in fact the current of air may be said to have been red hot. Under these circumstances it was almost impossible to avoid the fusion of the lead tube which conveyed the hot air from the heater. This great difficulty, combined with some minor ones which, however, might be obviated, caused the inventor to relinquish the idea. Although not an invention or process capable of being carried on in its present shape, yet, in the hands of a patient operator, it might be made to yield better results. It would probably be a work of no little trouble and expense, yet if the anticipated result could be obtained, it would amply repay any trouble or expense that might be expended upon it.

Fig. 597.



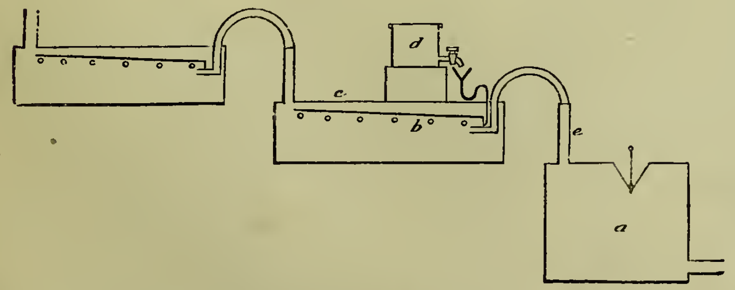
Proposed Improvements in Manufacturing Sulphuric Acid.—The efforts of inventors in connection with sulphuric acid, would appear to have been directed to the substitution of some apparatus of smaller bulk, and less costly in construction, than the leaden chambers ordinarily employed. Perhaps the simplest process embodying the above idea is that of Messrs. M'Dougall and Rawson, who included it in a patent obtained by them in 1848. It consists essentially in passing a stream of sulphurous acid gas through nitric acid by which sulphuric acid and binoxide of nitrogen — NO_2 — are obtained as follows:—

$$3\,SO_2 + NO_5 = 3\,SO_3 + NO_2,$$

but the great point of the process is the continual conversion and reconversion of this NO_2 into nitric acid, to be again used as before. The inventors say, that the reaction which ensues may be best described by symbols. Thus when 3 NO_4—the NO_2 evolved in the first reaction becoming NO_4 by combining with the excess of oxygen, which as atmospheric air accompanies the sulphurous acid—is passed into water at a temperature of 100°, or upwards, 2 NO_5 + NO_2 results. This NO_6— or, two atoms of nitric acid—remains in solution, while the NO_2, which is an incondensable gas, bubbles through the liquid, and, mixing with the air which is above the liquid, instantly takes two atoms of oxygen from it, and becomes NO_4; which, passing again through the liquid, becomes nitric acid and nitrous gas as before: and thus nearly the whole of the nitrous fumes or gas is reconverted into nitric acid. It should be observed that the use of this reaction is claimed in connection with several processes, such as the manufacture of oxalic acid, *et cetera;* but with regard to sulphuric acid, they further say—In our improved method of manufacturing sulphuric acid, we use a series of vessels, similar to that described in the first part of our invention—a modification of Woulfe's bottles, in fact—only that the first vessel of the series is connected with a sulphur burner. The mode of working is to fill the first vessel two-thirds full of nitric acid, and all the others one-third full of water, to charge the burner with sulphur, and then to put in motion the pneumatic apparatus connected with the last vessel of the series. Air is thus drawn over the ignited sulphur, so that sulphurous acid and air pass into a solution of nitric acid in the first vessel, when a portion of the sulphurous acid is converted with sulphuric acid, at the expense of the nitric acid; while the uncondensed sulphurous acid passes into the air, and nitrous gas into the next vessel; and so, as in the first part of the invention, we pass it alternately into water and air, till the processes of oxidation and condensation are complete. When the working has been continued for some time, we find that the nitric acid has entirely passed from the first vessel, and we have in its place sulphuric acid nearly pure. The same would take place with each of the other vessels of the series, if the nitric acid which has been condensed in the vessels lower in the series, was not again returned to the higher ones, so that when we find the first vessel exhausted of its nitric acid, we remove the sulphuric acid which it contains, and supply it again with nitric acid, obtained from vessels lower in the series. We thus produce sulphuric acid without the loss of nitric acid; as the lower oxides of nitrogen, given off in the oxidation of sulphuric acid, are again converted into the higher oxides, and again used for the conversion of sulphurous acid into sulphuric.

The principle embodied in this process, namely, the perfect recovery of the nitric acid, has been the prevailing idea of many inventors. Some of the other processes to be described are based on the same reaction. About the same time as the date of the above patent, an ingenious modification of their process was being experimented on, of which the following description is an outline:—The apparatus consisted of a burner for the production of sulphurous acid, and an ingenious substitute for the Woulfe's bottles of the last-described process. The burner, *a*—Fig. 598—consisted of an iron chamber, closed up tight, with the exception of an inlet pipe for the admission of air for combustion, and an exit pipe for the sulphurous acid, proper means being allowed for the introduction of the sulphur. The condensing or the conversion part of the apparatus consisted of two leaden troughs or cisterns; but, as they were exact counterparts of each other, a description of one will suffice. This trough, shown in section in the figure, has, what may not be inappropriately called a false top, *b*, a few inches below the real top, *c*. This false top, which was to all intents a sort of shelf, had borders or edges soldered on to it in such a manner that had it been taken out and laid down with its under side upwards, it would have resembled a large, shallow, square dish. This shelf, as just stated, was fastened inside the cistern, within a few inches of the top, and in an inclined position, so that one end was rather higher than the other by about two inches, thus giving it a gentle slope—the use of this will be seen when describing its action.

Fig. 598.



To work this apparatus the two cisterns were first filled with water or weak vitriol, and the vessel, *d*, was filled with nitric acid; a quantity of sulphur was introduced into the burner, and a coal fire ignited beneath it; a stream of air was then turned on through the tube shown in front of the burner, this stream of air being supplied by a pair of bellows, or other suitable apparatus; when the burner attained a sufficiently high temperature, the sulphur ignited; sulphurous acid became generated; this proceeded along the pipe, *e*, and was discharged beneath the shelf, *b*. At this point it was met by a small stream of nitric acid, which trickled from the vessel, the gases rolled beneath the shelf, and from thence beneath the shelf of the second vessel. The reactions, it is scarcely necessary to observe, must have been precisely the same as those in the last-described process; the gases in this case being kept continually in contact with both air and water, and not alternately, as in the former case.

If, in the instances last given, the recovery and *ad infinitum* use of the nitrous gas has been the object, other methods have been invented or discovered by which the use of this body is proposed to be dispensed with altogether. In this latter class of projects, the oxidation of the sulphurous acid has been sought to be effected by the use of some catalytic agent, no cheap chemical body of an oxidizing character having presented itself capable of successfully rivalling the nitrates. The use of spongy platinum, in consequence of its possessing the requisite property in a high degree, naturally was the first suggestion. Parnell says this was attempted by Mr. Peregrine Phillips. His process consisted in simply mixing the sulphurous acid with excess of oxygen in the shape of atmospheric air, and passing this mixture over balls of spongy platinum at a red heat. The combination took place, and the vapor was received and brought to a liquid state by means of a condenser, like those already described, consisting of a column filled with pebbles, kept constantly wet by a stream of water.

Eventually it was discovered that platinum was not the only body adapted to the purpose; other porous materials, it was found, were capable of effecting the desired union of oxygen and sulphurous acid: for Schneider states that he has succeeded in converting sulphurous acid directly into sulphuric acid by means of a porous body, for instance, pumicestone, and that this process may be employed for manufacturing sulphuric acid of 170° Twaddell, without the necessity of leaden chambers or of platinum retorts. This has the advantage of being an immeasurably cheaper material although it can scarcely be so active.

M. Blondeau describes another process of the same nature as the last. The author has studied the production of sulphuric acid in certain natural conditions. He instances the Rio Vinagre Pasiambo in

South America, the water of which, he says, according to an estimate of Boussingault, supplies something like thirty-four tons of sulphuric acid in twenty-four hours; and also another instance in which three times this quantity was produced. M. Blondeau also examined the production of certain natural sulphates, such as those of potassa, soda, alumina, *et cetera*, and the conditions under which they are produced. Reasoning from his observations, he was induced to try whether certain natural conditions, under which sulphuric acid was produced, could not be imitated in the laboratory; he succeeded in the following manner:—A quantity of argillaceous sand was placed in a porcelain tube laid across a furnace, an apparatus for generating sulphurous acid was attached to one end, together with a tube from a gasometer containing air, and a retort for generating steam. A tube was attached to the other end of the retort, which led into a small vessel containing water, for the purpose of condensing any sulphuric acid which might be formed. The tube was heated red hot, and a slow stream of mixed air, steam, and sulphurous acid was passed through it. At the end of the experiment a quantity of sulphuric acid was found in the condensing flask. M. Blondeau suggests this as a mode of making sulphuric acid on the large scale.

Wöhler has given us the results of some interesting experiments on the production of sulphuric acid by the instrumentality of certain metallic oxides, some acting catalytically, others as simple oxides, yielding up a portion of their oxygen, themselves being converted into lower oxides. He passed a mixture of sulphurous acid and oxygen over several metallic oxides placed in a porcelain tube, and kept at a red heat; but he does not say whether he passed water vapor simultaneously with them. He says that oxide of copper, sesquioxide of iron, and oxide of chromium, each separately employed, instantly caused the production of dense white fumes of sulphuric acid. A mixture of oxide of copper and oxide of chromium, prepared by precipitation, had in particular a very energetic action. The same amount of oxide appeared capable of converting an indefinite quantity of the gases into sulphuric acid. He goes on to say that the production of sulphuric acid proceeds so readily that the process will undoubtedly become practically employed. When sulphurous acid alone is passed over oxide of copper or iron, the first is reduced to red oxide—Cu_2O,—and the latter to black oxide—Fe_3O_4—with production of sulphuric acid vapors; but which, however, cease to appear as soon as the reduction is complete. Wöhler gives the reaction of several other bodies; he also states that sulphurous acid, oxygen, and water vapor, passed through a tube alone, do not give rise to any sulphuric acid.

These ideas of Wöhler appear not to have passed without notice, but on the contrary have been most unceremoniously claimed and patented.

Mr. G. Robb, in a patent which he obtained, March 26th, 1853, proposes passing sulphurous acid and heated air over the surface of heated sesquioxide of iron —sulphuric acid is the product. He proposes also to take up the sulphuric acid as formed, by passing sulphurous acid mixed with air over a mixture of sesquioxide of iron and common salt—sulphate of soda is formed.

Alfred Trueman obtained a patent for improvements in the manufacture of sulphuric acid when roasting copper ores, *et cetera*. This invention consists in passing the sulphurous acid resulting from the roasting copper ores, mixed with oxygen, atmospheric air, or other suitable material containing oxygen, in contact with heated *platinum*, *oxide of iron*, or other substance, having in a heated state the property of causing the combination of sulphurous acid and oxygen. The inventor also claims these bodies when diffused in burnt clay, pumicestone, or other suitable body.

Another process proposed for the manufacture of sulphuric acid is that of M. Margueritte. It is entirely different from any yet described; it consists essentially in the separation of the already formed sulphuric acid from sulphate of lime. It is as follows:—Phosphate of lead is decomposed by hydrochloric acid; the phosphoric acid thus obtained is mixed with sulphate of lime, and the mass is calcined, when phosphate of lime remains and sulphuric acid is expelled. The phosphate of lime is decomposed by boiling with the chloride of lead already obtained, when phosphate of lead is again produced; this is again decomposed by hydrochloric acid, and the phosphoric acid set free again employed in the decomposition of a fresh portion of sulphate of lime. In this process the hydrochloric acid is lost in the form of chloride of calcium. It must consequently always be replaced, but when the sulphuric acid produced is employed in the decomposition of common salt for the production of sulphate of soda, the necessary quantity of hydrochloric acid is always reproduced, with the exception of unavoidable losses. By this process sulphuric acid may be separated from sulphate of baryta and other sulphates. He then proceeds to state that, if necessary, quantities of hydrochloric acid may be obtained from chloride of magnesium by heating it to redness when it is decomposed, especially when mixed with clay. This process is, however, not very likely to come into operation; it would require more hydrochloric acid than the author appears to calculate upon. If the composition of bone earth were $CaO\ PO_5$, there would be a possibility of making vitriol by the reproduced hydrochloric acid.

Sulphate of lead has been patented for the same purpose, by decomposing it with strong hydrochloric acid—

$$\underbrace{PbO, SO_3}_{\text{Sulphate of lead.}} + \underbrace{HCl}_{\text{Hydrochloric acid.}} = \underbrace{PbCl}_{\text{Chloride of lead.}} + \underbrace{HO\,SO_3}_{\text{Sulphuric acid.}}$$

Impurities in Sulphuric Acid.—Sulphuric acid of commerce invariably contains lead. It is not difficult to account for the presence of this body when one reflects how much the acid is in contact with this metal in the chambers, concentrating pans, *et cetera*. Lead always makes its appearance as sulphate when strong acid is diluted with water, the concentrated liquid being able to dissolve a portion of this salt which, when diluted, it is not able to retain. Nitrous compounds are found also, together with traces of hydrochloric acid. Traces of selenium have also been detected. Arsenic is a common impurity, derived usually from the iron pyrites, from which much acid is made. Traces of arsenic have also been detected even in vitriol made from commercial sulphur. Sesquisulphate of iron has also been found to be present. For the great majority of purposes these impurities are not found inconvenient in the arts; while, on the other hand, for some special uses, a process of purification must be had recourse to.

Purification.—When this is required for analytical or other purposes, distillation must be had recourse to. This, in the case of sulphuric acid, is a disagreeable process, not altogether free from danger, from the violent concussions occurring in the retort. It is usual to put a quantity of strips or fragments of platinum into the acid to obviate this bumping. A very simple condensing arrangement is necessary. The beak of the retort merely requires insertion rather loosely into the neck of a flask or wide tube.

For the purification of sulphuric acid from peroxide of nitrogen, nitric, or arsenious acids, Dr. J. Löwe recommends heating it, in the first place, with oxalic acid. This acid, heated with strong sulphuric acid, becomes first dehydrated, and then, as is well known, decomposes. Carbonic acid and carbonic oxide gases are given off. This carbonic oxide, being in the nascent state, has a strong tendency to deoxodize any highly oxidized body; therefore the peroxide of nitrogen and nitric acid give up a portion of their oxygen, becoming reduced to nitrogen, or nitrous oxide—NO—which bodies are not capable of being retained by the sulphuric acid, and therefore fly off. A temperature of 230° is requisite; at this heat the oxalic acid readily decomposes; it is added to the sulphuric acid, to be purified in small proportions in a dry state, as long as the sulphuric acid continues of a yellow tinge, and until a sample allowed to cool fails to show the presence of nitrous compounds, when heated with protosulphate of iron. The same author proposes eliminating the arsenic from sulphuric acid by converting it into chloride of arsenic, which is very volatile. The vitriol is heated in a flat dish, and small quantities of finely powdered chloride of sodium are added, stirring all the while with a glass rod. The arsenic passes off; the following being the reaction, the arsenic existing as arsenious acid:—

$$3\ (SO_3\ HO) + 3\ (NaCl) + AsO_3 = 3\ (NaO\ SO_3) + AsCl_3 + 3\ HO.$$

The operation must be conducted under a chimney, or other place where the arsenical fumes will be instantly carried off, so as not to injure the operator.

To avoid the troublesome and dangerous process of distillation, Augustus A. Hayes proposes to purify sulphuric acid in a very simple manner, namely, by crystallizing it. He first adds a small quantity of saltpetre to the acid while hot, in the leaden pan, and at a density if cold of 1·760. This destroys all organic matter, brownness disappears, and the acid becomes clear. A little sulphate of ammonia is now added, to destroy any excess of nitrate, as well as any nitrous compound already existing in it. The acid is now concentrated to a density of 1·780, and run off into deep vessels of lead, which are allowed to cool to a temperature of 32°; they stand so until clear; they are then run off into shallow lead vessels, so placed that they may become refrigerated to 0°. The acid, which has now nearly the composition $SO_3\ 2\ HO$, would solidify if allowed to remain long enough; but the vessels must stand only until one half the bulk has assumed the crystalline state; the mother liquid is then poured off. This mother liquid may be used for any ordinary purposes, such as the decomposition of nitrates, common salt, *et cetera.* The crystals are broken up after being washed with pure acid of a former operation, and are fused in a glass or porcelain vessel, when they form pure sulphuric acid.

Detection and Estimation of Sulphuric Acid.—Sulphuric acid is detected by means of a salt of baryta—this earth being capable of separating it from almost any combination, forming with it sulphate of baryta. In some cases, when testing for sulphuric acid, it is necessary to be very cautious; for instance, when endeavoring to ascertain its presence or otherwise in the nitric or hydrochloric acid of commerce, it is necessary to dilute these acids before adding a salt of baryta. If this is not done the nitrate of baryta, or chloride of barium, will itself be thrown down as a crystalline precipitate, liable to be mistaken for sulphate of baryta; but, if so, the addition of water to the precipitate will cause it to disappear, which will not be the case if the precipitate is sulphate of baryta. This latter salt, being very insoluble in water, furnishes us with a correct method of estimating sulphuric acid; for this purpose a weighed portion of the acid or any of its salts is placed in a beaker glass, and diluted with or dissolved in water. If it is a sulphate, the solution should be made *slightly acid* with nitric or hydrochloric acid, but if it is sulphuric acid alone that is being examined this addition is unnecessary; in either case the liquid is boiled, and, while boiling, a solution of chloride of barium or nitrate of baryta is poured in; the whole is allowed to boil a little longer, when it is removed to cool and settle. A little of the clear liquid above the precipitate is then tested, by the addition of a fresh portion of the baryta salt. If a precipitate is produced, it shows that all the sulphuric acid has not been thrown down, in which case it is necessary to add more of the barytic solution and boil again; if, after settling and further addition of baryta, no precipitate is produced, the whole must be thrown on to a filter, washed carefully with hot water, and dried. It is then ignited in a platinum or porcelain crucible and weighed; 116·6 parts, or one equivalent of sulphate of baryta, are equal to forty-nine parts, or one equivalent of monohydrated sulphuric acid, or forty parts of anhydrous acid. This method would be found too tedious to follow, except on special occasions; ordinarily the manufacturer relies on the indications of his hydrometer—that is, he takes the density for his guide. To enable us to arrive at the real value of the sulphuric acid from the density, several tables have been drawn up, of these. Dr. Ure's is commonly used.

AMOUNT OF DRY ACID IN SULPHURIC ACID.

$SO_3\ HO$.	Specific gravity.	SO_3.
100	1·8485	81·54
99	1·8475	80·72
98	1·8460	79·90
97	1·8439	79·09
96	1·8410	78·28
95	1·8376	77·46
94	1·8336	76·65
93	1·8290	75·83
92	1·8233	75·02
91	1·8179	74·02
90	1·8115	73·39

AMOUNT OF DRY ACID IN SULPHURIC ACID—*Continued.*

SO_3HO	Specific gravity.	SO_3
89	1·8043	72·57
88	1·7962	71·75
87	1·7870	70·94
86	1·7774	70·12
85	1·7673	69·31
84	1·7570	68·49
83	1·7465	67·68
82	1·7360	66·86
81	1·7245	66·05
80	1·7120	65·23
79	1·6993	64·42
78	1·6870	63·60
77	1·6750	62·78
76	1·6630	61·97
75	1·6520	61·15
74	1·6415	60·34
73	1·6321	59·52
72	1·6204	58·71
71	1·6090	57·89
70	1·5975	57·08
69	1·5868	56·26
68	1·5760	55·45
67	1·5648	54·63
66	1·5503	53·82
65	1·5390	53·00
64	1·5280	52·18
63	1·5170	51·37
62	1·5066	50·55
61	1·4960	49·74
60	1·4860	48·92
59	1·4760	48·11
58	1·4660	47·29
57	1·4560	46·48
56	1·4460	45·66
55	1·4360	44·85
54	1·4265	44·03
53	1·4170	43·22
52	1·4073	42·40
51	1·3977	41·58
50	1·3884	40·77
49	1·3788	39·95
48	1·3697	39·14
47	1·3612	38·32
46	1·3530	37·51
45	1·3440	36·69
44	1·3345	35·83
43	1·3255	35·06
42	1·3165	34·25
41	1·3080	33·43
40	1·2999	32·61
39	1·2913	31·80
38	1·2826	30·98
37	1·2740	30·17
36	1·2654	29·35
35	1·2572	28·54
34	1·2490	27·72
33	1·2409	26·91
32	1·2334	26·09
31	1·2260	25·28
30	1·2184	24·45
29	1·2108	23·65
28	1·2032	22·83
27	1·1956	22·01
26	1·1876	21·20
25	1·1792	20·38
24	1·1706	19·57
23	1·1626	18·75
22	1·1549	17·94
21	1·1480	17·12
20	1·1410	16·31
19	1·1330	15·49
18	1·1246	14·68
17	1·1165	13·86
16	1·1090	13·05
15	1·1019	12·23
14	1·0953	11·41
13	1·0887	10·60
12	1·0809	9·78
11	1·0743	8·97
10	1·0682	8·15
9	1·0614	7·34
8	1·0544	6·52
7	1·0477	5·71
6	1·0405	4·89
5	1·0336	4·08
4	1·0268	3·26
3	1·0206	2·45
2	1·0140	1·63
1	1·0074	0·82

In this table there is opposite a list of different densities, the quantity of dry acid per cent., either dry or monohydrated. To bring the degrees of Twaddell's hydrometer to those of the real specific gravity, it is only necessary to multiply the first by five, and add one thousand; thus, supposing a sample of vitriol to stand 150° on Twaddell's hydrometer, multiply this 150° by 5°, and one has 750°; to this add 1000°, and the specific gravity, 1·750° is obtained. Now, to ascertain the amount of real sulphuric acid in this sample, it is only necessary to run through the table and find the density 1·750°, or the nearest approach to it, which in this case is 1·746°. It will be found then that the sample would contain eighty-three per cent. of the monohydrated acid, or 67·68 per cent. of dry acid.

This method of arriving at the value of a sample, though very convenient, is liable to error; for instance, the sample might contain foreign matter dissolved in it; this would augment the density, and cause it to appear of more value than it really is. A slight change of temperature also will alter the density considerably. The following table, the production of Mr. Parkes, shows the gradual lowering of the density as the temperature increases, so that, even though the sample may be free from foreign bodies, error may creep in. From this table it is evident, that the density of all samples of vitriol should be taken, as in the case of Dr. Ure's table, at as near as possible 60°.

PARKE'S TABLE OF VARIATIONS IN DENSITY OF CONCENTRATED SULPHURIC ACID THROUGH CHANGE OF TEMPERATURE.

Temperature Fahrenheit.	Density.
30°	1·8593
32	1·8563
36	1·8546
38	1·8532
40	1·8527
42	1·8520
44	1·8522
46	1·8519
48	1·8517
52	1·8511
56	1·8500
60	1·8468
63	1·8449
68	1·8435
70	1·8430
74	1·8413
80	1·8381
84	1·8343

Again, when the density of a sample is high, it is difficult to estimate it with sufficient accuracy. If one examine Dr. Ure's table, he will find that acid of 1·8439 specific gravity contains ninety-seven per cent. of monohydrated acid, while the density of the monohydrated acid itself is but 1·8485—thus the slight difference of ·0046, or rather less than one degree on the hydrometer, equals three per cent. To obviate this, Dr. Dalton proposed that the boiling point should be taken as the guide, instead of the specific gravity, inasmuch as it permits a range of ten or twelve degrees for one per cent. of real acid. For this purpose he drew up the following table:—

DR. DALTON'S TABLE OF BOILING POINTS OF SULPHURIC ACID AT DIFFERENT STRENGTHS.

Specific gravity.	Dry acid per cent.	Boiling point.
1·850	81	620°
1·849	80	605
1·848	79	590
1·847	78	575
1·845	77	560
1·842	76	545
1·838	75	530
1·833	74	515
1.827	73	501
1·819	72	487
1·810	71	473
1·801	70	460
1·791	69	447
1·780	68	435
1·769	67	422
1·757	66	410
1.744	65	400
1·730	64	391
1·715	63	382
1·699	62	374
1·684	61	367
1·670	60	360
1·650	58·6	350
1·520	50	290
1·408	40	260
1·300	30	240
1·200	20	224
1·100	10	218

In addition to these methods, there may be mentioned that of testing the value of vitriol by an acidimetrical process, with a standard solution of alkali.

Mr. PETER HART, of Manchester, kindly supplied some valuable information which the Editor has incorporated in this monograph.

TARTARIC ACID—$2\ HO, C_8 H_4 O_{10}$—*Acide tartarique*, French, *Weinsteinsaure*, German—was first obtained in a separate state by SCHEELE in 1770. It is found partly free, partly combined with bases in many plants. It exists most largely in grape-juice, but it is met with also in tamarinds, and the berry of the mountain ash; in madder, potatoes, cucumbers, quassia, squills; in mulberries, pine apples, *et cetera.*

Preparation.—In order to prepare the acid, four parts of crude tartar—*argol*—are suspended in boiling water, and one part of chalk added. As soon as the effervescence entirely ceases, and the liquid no longer reddens litmus, the tartrate of lime is allowed to settle at the bottom, and the clear tartrate of potassa decanted. The change which takes place, is as follows :—

$$\underbrace{2\ (KO, HO, C_8 H_4 O_{10})}_{\text{Cream of tartar.}} + \underbrace{2\ (CaO, CO_2)}_{\text{Carbonate of lime.}} = \underbrace{2\ CaO, C_8 H_4 O_{10}}_{\text{Tartrate of lime.}}$$

$$+ \underbrace{2\ KO, C_8 H_4 O_{10}}_{\text{Tartrate of potassa.}} + 2\ CO_2$$

The dissolved tartrate of potash may be further decomposed by chloride of calcium : thus—

$$2\ KO, C_8 H_4 O_{10} + 2\ CaCl = 2\ KCl + 2\ CaO, C_8 H_4 O_{10}$$

The well-washed precipitates are digested with sulphuric acid diluted with ten parts of water, five parts of the tartar employed requiring three parts of the acid. Sulphate of lime is formed, and tartaric acid set free. On evaporating the filtered solution in leaden vessels to the consistence of sirup, tartaric acid crystallizes in large, transparent, colorless, oblique rhombic prisms of agreeable sour taste, and specific gravity 1·75; is readily soluble in water and alcohol; unalterable in air. When greatly heated, the crystals become strongly electrical. Boiled with nitric acid, tartaric acid is decomposed into acetic, oxalic, and saccharic acids. Boiled with hyperoxide of lead, it becomes oxidized and changed into formate of lead, water, and carbonate of lead, thus—

$$\underbrace{2\ HO, C_8 H_4 O_{10}}_{\text{Tartaric acid.}} + \underbrace{6\ PbO_2}_{\text{Hyperoxide of lead.}} = \underbrace{2\ (PbO, C_2 HO_3)}_{\text{Formate of lead.}} +$$

$$\underbrace{4\ (PbO, CO_2)}_{\text{Carbonate of lead.}} + \underbrace{4\ HO}_{\text{Water.}}$$

If heated with alkalies, a mixed oxalate and acetate results, with evolution of water, thus—

$$\underbrace{2\ HO, C_8 H_4 O_{10}}_{\text{Tartaric acid.}} + \underbrace{3\ (HO, KO)}_{\text{Potassa.}} = \underbrace{2\ (KO, C_2 O_3)}_{\text{Oxalate of potash.}} +$$

$$\underbrace{KO, C_4 H_3 O_3}_{\text{Acetate of potassa.}} + \underbrace{6\ HO}_{\text{Water.}}$$

Mixed with spongy platinum and heated in a stream of oxygen, tartaric acid is at 482° completely resolved into carbonic acid and water.

The action of heat upon tartaric is as instructive as it is remarkable.

It melts between 338° and 356°, and without losing weight is changed into a mixture of two acids—metameric with tartaric acid.

METATARTARIC ACID—$C_8 H_6 O_{12}$; or $2\ HO, C_8 H_4 O_{10}$—forms a transparent vitreous mass. It is bibasic, but its salts are more soluble than the corresponding ones of tartaric acid.

ISOTARTARIC ACID—$HO, C_8 H_5 O_{11}$—is monobasic. Its salts are isomeric with the bitartrates, but very much more soluble. Solutions of isotartrates as well as of metatartrates are changed by boiling into tartrates.

If tartaric acid be heated to 374° it fuses : two equivalents lose one equivalent of water and become changed into an acid, called by FRÉMY, TARTRALIC ACID—$3\ HO, C_{16} H_8 O_{20}$.

If the heat be still longer continued tartaric acid loses half its basic water and becomes TARTRELIC ACID—$2\ HO, C_{16} H_8 O_{20}$.

Most probably both tartralic and tartrelic acids are mere combinations of anhydrous tartaric acid with varied proportions of crystallized tartaric acid.

If the heat—374°—be carefully maintained for yet a longer time, ANHYDROUS TARTARIC ACID OR TARTARIC ANHYDRIDE remains in form of a white, porous mass insoluble in water. Adherent tartrelic acid is removed by washing with water till the wash liquor no longer reddens litmus. By contact with cold water for a few hours anhydrous tartaric acid resumes its basic water.

Small quantities of tartaric acid are completely decomposed in an oil-bath at 512°, leaving only a slight carbonaceous residue.

Tartaric acid is much used by dyers and calico-printers for the removal of certain mordants from portions of the cloth. It is also used in preparing effervescing draughts. In the blood, tartrates are changed into carbonates.

Aqueous solutions of tartaric acid, especially when hot, exercise right-handed rotation upon polarized rays of light—the angle of deviation corresponds to the quantity of acid traversed by the ray.

Tartaric acid is *bibasic;* its salts are tartrates.

Bitartrate of Potassa—$KO, HO, C_8 H_4 O_{10}$—is the *cream of tartar* or *argol* of commerce, and is obtained chiefly as an incrustation from the inside of wine casks. It crystallizes in hard, opaque, oblique rhombic prisms, of snowy whiteness when pure, and of sour taste; soluble in one hundred and eighty parts of cold and six of boiling water; in alcohol nearly insoluble. Heated to redness in close vessels, a mixture of carbonate of potassa and charcoal results—much used as *black flux*. Calcined with its own weight of nitre, *white flux*, or carbonate of potassa, is obtained.

Neutral Tartrate of Potassa—$2 KO, C_8 H_4 O_{10}$—by slow evaporation in transparent, colorless prisms, somewhat deliquescent, and very soluble.

Bitartrate of Soda—$NaO, HO, C_8 H_4 O_{10}, 2 HO$—in transparent, colorless, right rhombic prisms, from a hot solution of the neutral salt, mixed with half its weight of tartaric acid.

Neutral Tartrate of Soda—$2 NaO, C_8 H_4 O_{10}, 4 HO$—soluble in five of cold and half their weight of boiling water. In transparent, colorless, right rhombic prisms.

Neutral Tartrate of Potassa and Soda—$KO, NaO, C_8 H_4 O_{10} 8 HO$—is *Rochelle salt*, obtained by neutralizing cream of tartar with carbonate of soda. In large, transparent, colorless, right rhombic prisms, soluble in 2·62 parts of water at 42°. The salt is medicinal.

Bitartrate of Lithia—$LO, HO, C_8 H_4 O_{10}, 3 HO$—in small crystals, very soluble in water.

Neutral Tartrate of Lithia—$2 LO, C_8 H_4 O_{10}$—white, opaque, deliquescent.

Bitartrate of Ammonia—$NH_4O, HO, C_8 H_4 O_{10}$—in delicate needles, but little soluble in water. The crystals are in form of oblique rhombic prisms.

Neutral Tartrate of Ammonia—$2 NH_4O, C_8 H_4 O_{10}$—in oblique prisms, readily soluble, and with a taste like that of nitre.

Neutral Tartrate of Potassa and Ammonia—$KO, NH_4O, C_8 H_4 O_{10}$—in transparent, colorless prisms, isomorphous with neutral tartrate of potash.

Neutral Tartrate of Baryta—$2 BaO, C_8 H_4 O_{10}$—a crystalline powder, soluble in eight hundred parts of cold water.

Neutral Tartrate of Strontia—$2 SrO, C_8 H_4 O_{10}, 8 HO$—soluble in one hundred and forty-seven parts of water at 60°.

Bitartrate of Lime—$CaO, HO, C_8 H_4 O_{10}$—in the fruit of *Rhus typhinum*, in crystals, sparingly soluble in water.

Neutral Tartrate of Lime—$2 CaO, C_8 H_4 O_{10}$—occurs in grapes, and mixed with crude tartar; also in senna leaves. Neutral tartrate of potassa forms, with chloride of calcium, a crystalline precipitate—it is the salt obtained in making tartaric acid. Crystals, right rhombic prisms with octahedral summits; soluble in twelve hundred parts of cold water.

Bitartrate of Lime—$CaO, HO, C_8 H_4 O_{10}$—in the fruit of *Rhus typhinum*. The crystals dissolve in one hundred and forty parts of water and redden litmus.

Neutral Tartrate of Magnesia—$2 MgO, C_8 H_4 O_{10}, 8 HO$—obtained by digesting excess of magnesia alba in dilute tartaric acid. Crystalline crusts soluble in one hundred and twenty-two parts of cold water. Like tartrate of lime, the residue by ignition is pyrophoric.

Bitartrate of Magnesia—$MgO, HO, C_8 H_4 O_{10}$—when excess of acid is employed. Six-sided prisms soluble in fifty-two parts of cold water.

Tartrate of Alumina occurs in *Lycopodium clavatum*. Very soluble.

Tartrate of Lead—$2 PbO, C_8 H_4 O_{10}$—by precipitating neutral acetate of lead with tartaric acid. A white crystalline powder, almost insoluble in water.

Prototartrate of Iron is made from iron filings and dilute tartaric acid, with exclusion of air. A white powder requiring four hundred and twenty-six parts of cold water for solution. It is said to contain thirteen per cent. of water.

Pertartrate of Iron, by dissolving the freshly prepared hydrated peroxide of iron in solution of tartaric acid. Its solution is not precipitated by alkalies.

Potasso-tartrate of Iron—$KO, Fe_2 O_3, C_8 H_4 O_{10}$—is an important medicinal salt. It is obtained by digesting the hydrated sesquioxide of iron with water, and bitartrate of potassa at 125° for twenty-four to thirty-six hours, and evaporating the residue on plates. In lustrous scales of dark brown color.

Ammonio-tartrate of Iron—$NH_3, Fe_2 O_3, C_8 H_4 O_{10}, 4 HO$. Made like the previous salt, with substitution of bitartrate of ammonia. It is quite stable in composition when its solution is boiled.

Tartrate of Copper—$2 CuO, C_8 H_4 O_{10}, 6 HO$—by precipitation of acetate of copper with tartaric acid. A very light blue powder, soluble in one thousand seven hundred parts of cold water.

Potasso-tartrate of Copper—$KO, CuO, C_8 H_4 O_{10}$—by boiling oxide of copper in solution of cream of tartar. Crystals dark blue; very soluble.

Tartrate of Silver.—$2 AgO, C_8 H_4 O_{10}$—by mixing neutral tartrate of potash or Rochelle salt with nitrate of silver. A white, crystalline, lustrous powder; gently heated, spongy silver remains, with evolution of pyrotartaric and carbonic acids.

Potasso-tartrate of Antimony—$KO, SbO_3, C_8 H_4 O_{10}, HO$—is extensively used in medicine under the name of *tartar emetic*. Three parts of oxide of antimony are made into a thin paste with water, and mixed with four parts of bitartrate of potassa. The mixture is digested for several hours, and then boiled with eight parts of water. The boiling-hot solution is filtered and allowed to crystallize. Transparent or opaque, colorless, shining rhombic octahedra, of metallic taste. It is soluble in fifteen parts of cold and two of boiling water. In small doses it is an emetic; in larger doses it is a poison.

Of the heavy metals, iron is the only one which precipitates antimony completely from the aqueous solution of tartar emetic. Hydrochloric, nitric, and sulphuric acids precipitate a basic hydrochlorate, nitrate, and sulphate of the oxide of antimony.

There are several other antimonial tartrates, the place of potassa being supplied by soda, ammonia, lead, oxide, and silver oxide. A compound similar to tartar emetic may be formed with arsenious acid—($KO, AsO_3, C_8 H_4 O_{10}$).

TIN.—*Etain*, French; *zinn*, German; *stannum*, Latin.—Tin is the *Jupiter* of the alchemists. It is one of the metals which were known to the ancients, and is evidently of high antiquity, although, in all probability, gold, silver, copper, and iron were known much sooner. It is supposed by some that the original Hebrew term *bedil* of Holy Writ indicates this metal; but others infer that a compound or mixture resulting, perhaps, from the purification of gold and silver possessing an inferior value, was meant by it. Under the impression that the word above mentioned denoted tin, the Greek translators of the scriptures rendered it κασσιτερος, by which term the classic writers of profane history describe tin, after all doubt had been removed as to its identity. BECKMAN discusses the question whether the *stannum* of the Latins and the κασσιτερος of the Greeks was really the metal which forms the subject of the present article; and whilst he leaves the point undecided, advances various arguments to show that a rich alloy of silver and lead was frequently, if not always, the substance indicated by the foregoing titles.

Whatever may have been the nature of such alloys, it is certain, from the writings of DIOSCORIDES, DIODORUS, PLINY, and others, as well as from Celtic records, that tin was known at a very early period. It is recorded that between 1040 and 1030 before the Christian era, the Phœnicians had discovered that part of Britain known at present as Cornwall and Devon, and instituted searches for minerals and metals therein; and the active exportation of the metals—principally tin—led to the adoption of the title *Brectan*—red or burning fires and land—for the mainland, from the circumstance of large fires being kept burning on all the bold heights of the country to serve as beacons for the mariners along the dangerous coast; of which words Britain is but a slight modification. The metal tin was called in the dialect of the people of Phœnicia *stān*, whence the *stannum* of the Romans; from this root likewise has been derived the title *Stanneries*, which is still applied in Cornwall to the districts where tin is produced.

That the quantity of tin extracted from the British mines was considerable, is very evident even from the account of the Greek writers already alluded to; thus DIODORUS, in the second chapter of his fifth book, says—The inhabitants of that part of Breo-tan—Britain—called Bolerion—supposed to be the Land's-end, but actually a corruption of *Bal-erig*, which means the country of the *Erians* or *Iberians*, of which it is an abbreviation—excel in their hospitality; and also, from their converse with merchants, they are more civilized and courteous to strangers. These are the people who make the tin, which, with a great deal of care and labor, they dig out of the ground which is rocky; but it has in it earthy veins, the produce of which is brought down, melted, and purified. Then when they have cast it into the form of cubes, they carry it to an island adjoining to Britain called Iktis. During the recess of the tide the intervening space is left dry, and the tin is carried to the island in carts; and it is something peculiar that happens to the islands in those parts lying between Europe and Britain, for at full tide, the passage being overflowed, they appear islands; but when the sea returns, a large space is left dry, and they are seen as peninsulæ. From this the tin is transported to Gaul, through which it is conveyed on horseback in about thirty days to the mouth of the river Rhone.—*Diodorus.*

The island above alluded to will be at once recognized as one of the Scillies, and its Greek name was probably derived from its being made a fishing-station by the Phœnicians.

Of the mode of operations by which the tin was extracted, or the mines worked in those days, no record is left; but from the remains which have been discovered, it is conjectured that the methods adopted were of the rudest description. By whatever means the mining and metallurgy of tin were prosecuted in Cornwall and Devon up to the period of the Norman conquest, it is certain that after that event they received a great impetus, so that the chief part of the revenues of the Earls of Cornwall was derived from it. King John gave a charter to the Cornish tin mines in 1201; another was granted them in 1305 by Edward I., and the stannery laws were instituted in his reign. These laws are still extant, and partly in force; but want of space forbids a full account of them here. Previous to the thirteenth century England enjoyed a monopoly of the tin trade; but in that age rich veins of tin ore were discovered in Misnia and Bohemia; and about the year 1250 the English trade was much reduced by the low price at which the Germans were able to sell their tin. At present tin is found in several places, and mines of it are wrought in Bohemia, Saxony, and Austria; in Gallicia, on the borders of Portugal; at Piriac, in the *Loire inférieure;* and at Vaulry, in the department Haute Vienne in France; but the mines of French localities are of very little importance. Large quantities of tin ore occur in the Siberian mining district of Nertschinsk, and it is found in Dalecarlia in Sweden; but the richest deposits that have hitherto been found are those in the province of Tenasserim on the east side of the Gulf of Martaban in the Malayan peninsula; these have been worked for many centuries, and considerable quantities are still obtained. In the early part of the last century—1710—large quantities of very pure ore of tin were discovered in the island of Banca, whence as much as three thousand five hundred tons of the metal have some years been abstracted. Minerals of tin exist also in Brazil, in Mexico and Chili, in South America, in the United States, and Australia. The tin mining districts of Cornwall and Devonshire are three in number; namely, that included in the South-west of Cornwall beyond Truro, the neighborhood of St. Austell, and of Tavistock in Devonshire. The chief tin mines in these districts are Wheal Vor, near Helston; Polberrow, near St. Agnes; Polgooth, near St. Austell; Drake Walls, near Tavistock, on the Cornish side of the Tamar; and Birch Tor, also near Tavistock, but on the Eastern side in Devonshire. Ores of tin are found in all the localities mentioned, either in the form of regular lodes or veins disseminated in granite and in felspar—porphyry or elvan—and in alluvial formations on the slopes of hills, or in the valleys. In the former instances, the veins frequently cross one another either horizontally or in their perpendicular descent; occasionally they ramify through the rock in all directions, producing at the point of intersection masses of ore called by the Germans *stockwerk*, such as the Altenberg mine in Saxony. In the other instance of the occurrence of tin ore, namely, in alluvial deposits, it is usually called *stream tin*, as well from the nature of the deposit, as from the fact that in these cases the workings are generally in the course of rivulets or streams. It is found either in a pulverized sandy state, in separate stones, called *shodes* in Cornwall, or in a continued course of stones, which are sometimes found together in large numbers, and at depths varying from one to fifty feet. The course of these deposits is called a stream; but they have little regularity, varying in their breadth, and are scattered over the entire extent of the moor or valley in which they are found. *Wood tin*, the name given to pebbles of ore having a woody appearance, though now rather scarce, was formerly found in some of the stream-works of Cornwall.

MINERALS OF TIN.—Tin is found almost invariably in the form of binoxide of tin or tin-stone, and in some instances associated with iron and copper pyrites, forming what is called tin pyrites or bell-metal ore, but the quantity so existing is very small.

BINOXIDE OF TIN—*Cassiterite; tin-stone; zinnstein.*—This ore of tin, from which almost the whole of the metal is smelted, is found, as already mentioned, in different states of aggregation. It is characterized by a high gravity, averaging 6·3 to 7·1, adamantine lustre, and color varying from a brown or black to various shades of red, yellow, grey, and white. In crystalline shape it belongs to the right prismatic system, the crystals being twins, with some of the faces uneven, and others striated parallel to their intersections with each other. The crystals have but a very imperfect cleavage, their fracture is imperfectly conchoidal and their streak grey, and sometimes brown. Heated before the blowpipe, oxide of tin remains infusible *per se;* with soda in the reducing flame it affords small globules of metal. Acids do not exert a solvent action upon it, and therefore it cannot be dissolved till after its fusion with alkalies. In its pure state binoxide of tin contains—

	Atomic weight.		Centesimally.
1 Eq. of tin,	59	....	78·66
2 Eqs. of oxygen,	16	....	21·34
	75		100·00

Samples of the ore have been analyzed, and the results are stated thus—

	From Alternon in Cornwall, by Klaproth.	From Schlackenwald, by Klaproth.	From Finbo, near Fahlun, by Berzelius.
Oxide of tin,	98·93	99·28	93·6
Red oxide of iron,	0·32	0·72	1·4
Silica,	0·75	—	—
Columbic acid,	—	—	2·4
Binoxide of manganese	—	—	0·8
	100·00	100·00	98·2

This ore is found in the various localities already referred to, accompanied with quartz, mica, fluorspar, apatite, topaz, tourmaline, wolfram, heavyspar, mispickel in the lode; and in the alluvial beds of valleys and plains.

TIN PYRITES—*stannin; zinnkies.*—This ore of tin occurs in a few of the Cornish mines, such as those of Huel Rock in St. Agnes, and some of the granite veins in St. Michael's Mount; also at Zinnwald in Bohemia. Its crystalline form is cubic; the cleavage of the crystals is imperfect, the fracture uneven and conchoidal, the lustre metallic, with a steel-grey, inclining to bronze-yellow color, and a black streak. The specific gravity is 4·3 to 4·51.

Before the blowpipe on charcoal it melts in a strong heat, turns white on the surface, and deposits a fixed sublimate of binoxide of tin round the assay. After roasting, it affords, with the usual fluxes, the peculiar reactions of iron and copper, and a brittle globule of the latter metal on fluxing with soda and borax. Nitric acid decomposes it, dissolving the iron and copper, and leaving a deposit of sulphur and of binoxide of tin. The following analyses indicate the composition of a few samples of this ore; samples A and B from Huel Rock; C from St. Michael's Mount, and D from Zinnwald:—

	Klaproth.		Johnston.	Rammelsberg.
	A	B	C	D
Copper,	30·00	29·69	23·55	26·31
Iron,	12·00	12·57	4·79	6·80
Zinc,	—	1·79	10·11	6·93
Tin,	26·50	25·81	31 62	28·94
Lead,	—	—	—	0·41
Sulphur,	30·50	29·95	29·93	29·89
Loss,	1·00	0·19	—	0·72
	100·00	100·00	100·00	100·00

PREPARATION OF TIN.—The reduction of the ore is effected by roasting and smelting, in a manner similar to that which will be described further on, and the button so obtained is then treated in the following manner, to separate the metal from the arsenic, antimony, bismuth, zinc, lead, iron, and copper, one or more of which it may contain; or ordinary commercial tin may be taken for this purpose.

In either case the crude metal is treated with an excess of hydrochloric acid, when the tin, zinc, bismuth, copper, and iron are dissolved, whilst the arsenic and antimony will be separated; the former volatilized in the form of terhydride of arsenic, and the latter partly deposited as a black powder in the liquid, and partly dispelled as antimonide of hydrogen. The solution is filtered, and the liquid concentrated at a boiling temperature, and strong nitric acid in excess added, after which the evaporation is continued to dryness. The tin is thus obtained in the state of binoxide, which should be treated with a little hydrochloric acid, then filtered, washed thoroughly, and dried, mixed with charcoal, and reduced at a white heat in a charcoal-lined crucible.

Properties.—Tin is a white metal, having a metallic lustre, approximating to that of silver; it is softer than gold, but harder than lead, and has a specific gravity of 7·291. It is very malleable, so much so that it can be rolled into sheets of not more than the one-thousandth of an inch in thickness, but wanting ductility and tenacity to any useful degree. A wire of the metal, 0·7 of an inch in diameter, will sustain only thirty-four and a half pounds weight. Tin melts at 442°, and contracts slightly on cooling; at a strong red heat it emits white fumes, but the tension of its vapor is very feeble, and therefore little loss of metal is sustained. The metal exhibits a great tendency to crystallize when a mass of it is melted in a covered crucible, and allowed to cool very slowly; if before the bulk has solidified the fluid portion be poured off, the hardened part remaining in the vessel will be found crystallized in rhombic plates, according to PAJOT; and in octagonal needles, according to BROOKE. This tendency to crystallize is readily exhibited by dissolving the exterior coating of a plate of the metal by means of moderately dilute aqua-regia, and then washing off the acid with water. The surface will then exhibit a mottled appearance, owing to the irregular reflection of the fern-like crystals which the action of the acid reveals. Various pretty designs are in this way formed on the surface of moderately thick tinned plates; and the French, who practise the process for decorating snuff-boxes, *et cetera*, call it *moire metallique*. It is to the crystalline arrangement of the particles of the metal that the crackling sound which a bar of it emits on being bent backward and forward is due, the decrepitation being produced by the displacement of the small crystals of which the bar is composed. By repeatedly inducing this friction an amount of caloric is developed, which can be readily detected by a sensible calorimeter.

Tin retains its brilliancy for a considerable time when exposed to the air; when heated in the air to the melting point, however, it is immediately covered with a film of oxide of tin; and if the heat be increased, the oxidation of the metal becomes so rapid as to induce ignition. In both instances binoxide of tin results. The same change takes place when steam is passed over a bath of the metal heated to redness out of contact of air; for the metal abstracts the oxygen of the water, and sets free the hydrogen. Tin combines with most of the metalloids, producing generally two orders of combination, distinguished by the terms proto or stannous, and binary or stannic, compounds of such elements with the metal. The combination with many of these, as with sulphur, bromine, iodine, chlorine, *et cetera*, is so intense that, at a slightly elevated temperature the metal enters into active combustion, whilst the stannic salts of these radicals are produced Acids have likewise a well-marked action upon it; for instance, hydrochloric acid, at the ordinary temperature, slowly dissolves it, with evolution of hydrogen; at a boiling temperature the action is much more active; in both reactions the stannous chloride is formed. Dilute sulphuric acid, with the aid of heat, converts it slowly into a sulphate of the protoxide, and liberates hydrogen; the concentrated acid has little or no effect upon it in the cold, but if the liquid be heated to the boiling point, it rapidly attacks the metal, sulphurous acid being liberated. Slips of bright tin-foil, immersed in concentrated nitric acid, experience no change, however long they may be retained in it; but if the acid be diluted with water, the action becomes violent, owing to the rapid conversion of the metal to a binoxide of modified properties, known as metastannic acid, and the evolution of binoxide of nitrogen. If the nitric acid be previously diluted, no nitrous fumes are given off during the oxidation of the metal, but nitrate of ammonia is formed, thus—

$$\underbrace{4\,Sn}_{\text{Tin.}} + \underbrace{2\,HO, NO_5}_{\text{Nitric acid.}} + 2\,HO = \underbrace{4\,SnO_2}_{\text{Binoxide of tin.}} + \underbrace{NH_4O\,NO_5}_{\text{Nitrate of ammonia.}}$$

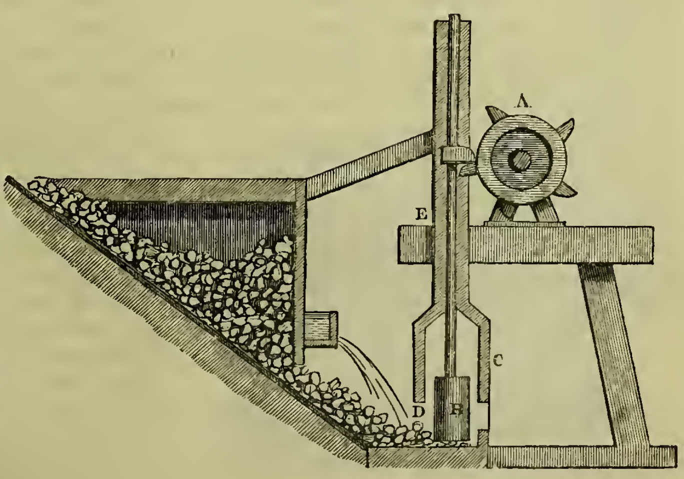
The fixed caustic alkalies dissolve tin, and produce with it a compound in which the combination of this metal takes the character of a salt radical; in this case water is decomposed and its oxygen is assimilated by the tin, whilst the hydrogen is given off.

The symbol for tin is Sn; its equivalent number 59.

METALLURGY OF TIN—*Preparation or Dressing of the Ore.*—In preparing ore of tin for the smelter, much pains are taken for the separation of all earthy matters and metallic substances that would reduce the per centage yield of the ore, or injure the quality of the tin when smelted. The order in which this dressing is performed is much the same as when copper ores are under treatment—namely, *cleaning* and *sorting* of the ore, *stamping* and *washing*, and, finally, *calcination* and *washing*.

Sorting the Ore.—This operation is commenced on the surface by washing away the clay and light impurities from the ore by a stream of water, and breaking or *spaling* the stones containing the ore, and separating the whole into heaps of different qualities and classes, according to the nature of the gangue, or the other minerals accompanying the tin; thus ores containing copper and iron pyrites are classed differently from such as contain only earthy matters, and such as contain tungsten are set aside by themselves to be submitted to a special treatment. The richest and purest lumps are placed together in heaps on the dressing floor, and are called *best work;* the second quality, though less rich than the preceding, are

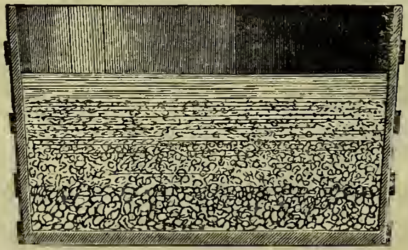
Fig. 599.



nevertheless remunerative; and the third division consists of matter that is very poor in, if not wholly without, ore.

The several heaps of ore are further reduced by the stamping mill to a fine powder. This *machine* is shown in section in Fig. 599. It consists of a wooden shaft, connected with a water-wheel or steam-engine, in which are arranged a number of cams that catch upon the lifting arms of a series of pestles heavily shod with iron, and secured in a strong wooden box lined with iron to prevent the dispersion in all directions of the ore by the strokes of the pestles or stamps. In the figure, A indicates the revolving shaft with the cams, B the pestle, and C the box confining them, D the ore to be crushed, and E a sluice which supplies a stream of water that carries off the reduced ore to the tanks along narrow inclined planes. Four stamping heads, averaging two and a half to three and a half hundredweight each, are worked in each box, and in the following order:—The pestle to the left of the spectator, supposed to be standing in front, first; the extreme right second; the right middle one third; and the left middle last—and each pestle is so lifted that the strokes follow in succession. The revolving shaft makes about twenty revolutions per minute, and the ore which enters the box receives from one hundred and sixty strokes to double this number to reduce it. The stream of water, entering the box from E, conveys the reduced ore, aided by the force of the pestles, through gratings at the ends and sides of the box to the inclined plane or cistern already mentioned. Here the ore, in consequence of its gravity varying in the ratio of its contents of metal, arranges itself into three kinds—the heaviest, and therefore the richest, resting on the upper part; a less rich ore in the middle; and the poorest or gangue parts—the tailings—at the lowest part. Very fine portions of the ore are carried off by the water in suspension to the slime pits, where it settles to the bottom, to be occasionally collected. The richest portion of the ore on the inclined plane is removed to the rectangular *buddle*, where it is washed under a regular stream of water, the ore being kept by a brush spread equally over the floor of the buddle. In this way the material is further purified, the richer ore remaining on the upper half of the table, and a poorer product on the lower half.

Fig. 600.

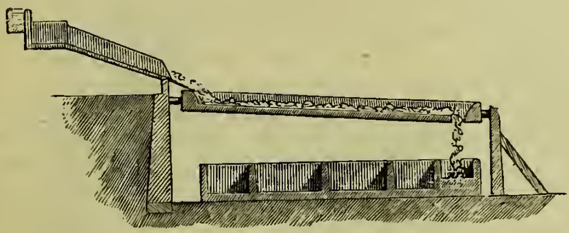


The richer ore is further purified in the *kieve*, or tossing tub—Fig. 600. It consists simply of a stout wooden vat, well bound with iron hoops, having a capacity of a hundred gallons or more. A quantity of the purer ore, from the buddle in the preceding instance, together with a quantity of water, is thrown into the tub and stirred well up with a shovel for a few minutes, and then allowed to rest, while to expedite the subsidence of the ore, the workman strikes the tub all round with a hammer. Here, again, a further separation of the ore takes place, according to the order of its gravity, the richer kinds being nearer the bottom of the tub, and forming distinct layers, as shown in the figure. The top layer is thrown away as being of little value, or is reserved for further washing in the circular buddle with other portions of poor ore; the second is submitted to another washing; and the lower layer is fit for the smelting furnace or the roaster, if it be pyritous, and is called *tin witts*.

The matter on the middle of the inclined plane or cistern adjoining the stamping mill is delivered into a wooden trough placed over the cistern, and washed by a small stream of water direct into the circular buddle, where the washing of ore is effected in larger quantity, and at less expense than in washing the rich ore as it becomes separated. Several of these circular buddles are required, and the lower layer of the deposit in one is conveyed by a trough to the next, and there washed. In this way the richer parts are removed from the poorer tailings; and when they arrive at the proper standard they are removed, and their cleansing finished on the rectangular buddle and tossing tub, as described. The contents of the slime pits are purified, first, by what is known as the *trunking process*, and secondly, on the *racking table*. The trunking box consists of a long sloping cistern, with a division near its upper end, forming a small quadrangular vessel, in which the ore, slime, and water are delivered. The contents of this small cistern are agitated by the slow movement of a paddle placed in it, and thus portions of slime and water are thrown out into the sloping trunk at each stroke. As it flows down this incline the heavier ore first separates, and continues to deposit, according to its density, towards the end of the trunk, where, however, the matter collected is of little worth. When enough of the mud is thus treated to fill the long cistern, the admission of more of the sludge is prevented, and the higher portion of the deposit is transferred to the *racking tables*, whilst the other portion is again submitted to the preceding trunking process. The racking table, shown in Fig. 601, is a long wooden table, set at an incline of one in sixteen, and having shallow bevilled flanges at the sides and ends to serve as a frame for it, and supported by centre pivots on a wooden framework about three feet high. At the head of the table is fixed the sloping board, hinged to it with leather, and upon this the mixture of ore and water is delivered, and a number of boxes, generally three, are fixed beneath it to receive the different qualities of the washed product.

About twelve or fifteen pounds of the selected stuff from the trunk boxes are placed on the fixed head and washed over the hinge board to the table. It is equally distributed over the board with the aid of a rake or brush, when the water sweeps along the lighter portions, and carries the worthless matter through a narrow slit at the bottom of the table into a gutter. The selected and rich deposit on the table is washed out into the receptacles beneath it by inclining the latter to one side, and a fresh quantity operated upon as before. The contents of the first, second, and third box are washed again on the rack once, twice, or thrice, as it is deemed necessary, before the product of the first vessel is sent to the tossing tub.

Fig. 601.



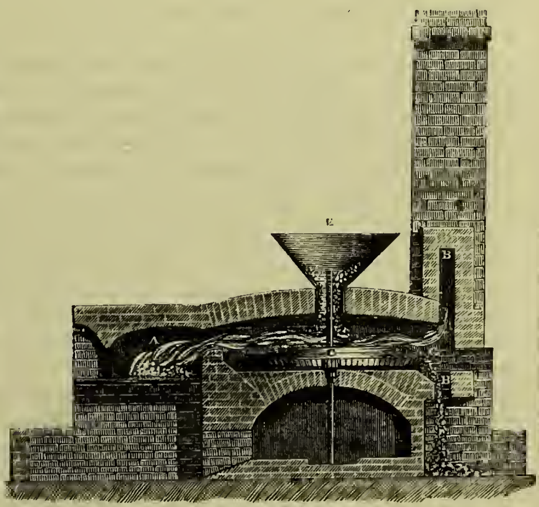
Stream tin is dressed by a similar course of operations as the foregoing, only that the ore is first treated in a large trunking box, where the workmen separate by a rake the larger from the smaller particles of ore. After this, the divisions of ore are submitted to a picking, stamping, and washing operation, mostly like that detailed above. With stream tin these processes serve to produce a very pure ore, devoid of most of its earthy components, and ready for the smelter; but when the tin is found in lodes, associated with copper and iron pyrites, the dressing course with simple washings is insufficient to remove the sulphurous compounds, and with which the ore cannot be smelted.

To remove them, the ore from the tossing tub—the *tin witts*—is conveyed to the burning house, and roasted in reverberatory furnaces, or in a kind of roaster called from its inventor Brunton's calciner. The reverberatories are of the usual form, having a bed about nine feet long, five feet wide in the middle, and four feet at the back part, wherein is situated the working door. The charge, amounting to ten or twelve hundredweight of ore, is let down upon the bed through a hopper in the arch, and when roasted it is drawn out to an arched space beneath the bed by a small aperture inside the working door in the latter. The temperature supplied should not exceed a dull red heat, such as will be capable of dispelling the arsenic and sulphur without fusing the sulphurous compounds. Frequent rabbling of the ore on the bed of the furnace expedites the separation of the sulphur and arsenic; but, under all the attentions given, the time for each charge averages, according to the amount of impurities, from eight to twelve hours. The arsenical and sulphurous vapors pass from the furnace into a wide flue, which is divided into a series of compartments or chambers of varied dimensions, for the purpose of arresting the arsenic, and leading to a low chimney usually erected on some adjoining and commanding eminence.

Brunton's calciner is shown in Fig. 602. It is a circular cast-iron table fixed on a stout central shaft, placed in proper bearings beneath the furnace, so as to permit its turning slowly with the table, c, which is set in motion by a small pinion gearing into a toothed wheel fastened to its under side. This table is fixed beneath the dome of a reverberatory furnace, having a hopper, E, for retaining the ore to be calcined, and in which the upper end of the central shaft turns and distributes the ore on the plate in a continuous stream. The fire is at A, and the products of its combustion pass over the ore to the flue, B, leading to the chimney. Owing to the revolution of the bed of the furnace the ore is kept constantly turned and moved till it travels to the circumference whence it is ejected through the apertures, H, into the receptacle or *wrinkle*, G, in the same ratio that it is supplied from the hopper. Power is communicated to the gearing pinion by a water-wheel or other means; and the rate at which the ore is to pass over the calciner is regulated by the quick or slow motion of this shaft. Much labor and fuel are said to be economized by the adoption of this system of roasting.

The roasting effects the conversion of the dense metallic sulphides into friable and light oxides, which, being of a less gravity than the tin ore that remains unaltered by the operation, can be readily separated by a proper system of washing. The several kinds of products from the preliminary dressing, such as jigged, fluran, smalls, slime, and roughs, are burned separately, and each subjected afterwards to a particular treatment; thus the jigged parcels are simply jigged again on a copper sieve after the burning; the fluran is passed through the buddle and tie, and the finer divisions are submitted to more complicated processes, consisting of *buddling*, *tossing*, *packing*, and further washing of the residues from these operations on hair sieves, till finally

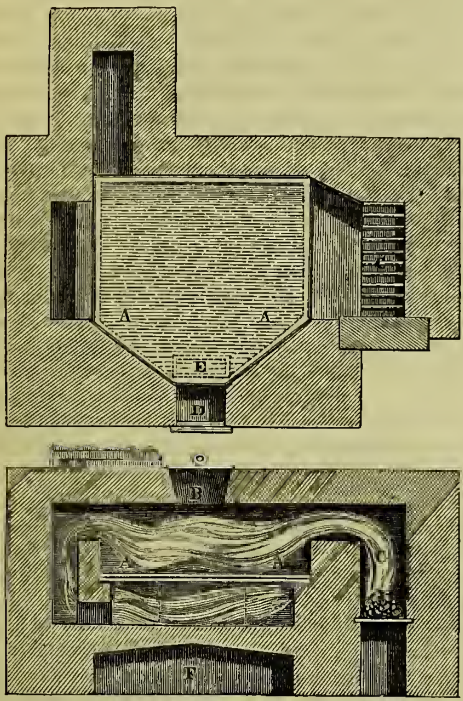
Fig. 602.



the tin crop remains as pure as possible. Numerous divisions of tin ores are made according to the quantity of the accompanying bodies and their nature, besides those already alluded to; and their dressing gives rise to several refuse matters, the purification of which necessitates a complication of operations, which are varied according to circumstances and the judgment of the superintendent of the mine. The *burned leavings* from the foregoing operations, containing more or less tin, are restamped with some silicious matter and rewashed; the crushing with the sand, *et cetera*, detaches from the particles of tin the earthy matters that were combined with them, and that rendered them specifically lighter in the preceding washings. They may now be readily separated by a stream of water in the trunking box or buddle, and the tin obtained.

Improvements in the Dressing of Tin Ore.—Several improved methods of purifying ores of tin have been suggested and practised during the last quarter of a century. The principal of these consist in the use of acids for the separation of the injurious matters from the tin ore, which remains unacted upon by them. By the use of hydrochloric and sulphuric acids the fragments of metallic iron from the tools of the miners, of oxides of iron, copper, *et cetera*, are dissolved and removed from the tin by simple washing, much more effectively, than could be done by any mechanical operation, however carefully performed. Acids have been in use for the dressing of tin ores since 1842, or earlier; muriatic acid being preferred where the impurity is iron and its oxide, and sulphuric acid for the separation of the copper existing in the roasted ore as oxide, which is afterwards thrown down from its solutions by metallic iron or zinc, and the sulphate of iron, or of zinc recovered. Longmaid's patent process of separating the sulphur from pyritic ores by fusing them with common salt, whereby the sulphur is converted into sulphate of soda, and the copper into the form of chloride, could be applied to the purification of tin ores containing the foregoing additional metals. Washing the roasted mass would remove the copper salt, and the sesquioxide of iron would be carried off in mechanical suspension, leaving the oxide of tin in a partially pure state behind. The preceding methods of treatment do not serve to purify ores of tin associated with *wolfram*—the double tungstate of iron and manganese—for this mineral has a density averaging 7·1 to 7·4, and therefore so closely approximating to that of tin that no amount of mechanical washing could part the two satisfactorily. Before the process for its purification was discovered, the tin obtained from this kind of ore was very inferior, and consequently the ores themselves were greatly depressed in value. By Oxland's method of removing the tungstic acid from them, however, they are so improved that first quality tin can be smelted from them, and necessarily with such purification their value has been correspondingly enhanced. The principle of Oxland's patent is that on fusing ores containing tungstates with alkaline salts, such as carbonates or sulphates of soda or potassa, the tungstic acid combines with the alkaline base, producing an alkaline tungstate, which may be dissolved out, and converted to useful purposes in calico-printing or painting, thus returning as much if not more than the expense involved in the treatment. The tin ore, as finely dressed as possible, is mixed with as much soda ash or crude soda as will be sufficient to form an alkaline tungstate with the amount of tungstic acid which analysis shows the mineral contains. The mixture is then introduced into the bed of a reverberatory, and heated to low redness, which temperature is sufficient to induce the combination of the alkali and the metallic acid body. When the operation is finished, as observed by the color the mass assumes, and the consistency of a thick paste which it takes, it is raked out by an opening in the bed of the furnace into a receptacle beneath, whence it is taken and cast into vats filled with water, which dissolves out the tungstate of soda, leaving the other constituents of the ore untouched. By a judicious use of the water and a properly-constructed vat, the whole of the tungstate can be extracted with very few changes of water, and without diluting the solution to an inordinate degree. While this operation is progressing, the furnace is being charged with a further quantity of the mixture, which is spread out upon the sole, and left so with the furnace doors closed, till the alkali begins to melt and the mass emits a hissing sound, resulting from the expulsion of carbonic acid from the soda salt by the metallic acid. It is then slightly stirred; and when the preceding noise subsides, and the forementioned indications are observed, the roasted mass is ready for drawing. Latterly, instead of carbonate of soda, or crude soda, sulphate of soda or *salt cake* has been substituted, both on account of its cheapness compared with soda ash, and of its answering all the required purposes, in this respect, as well as the latter salt. Some skill and practical judgment are required, however, on the part of the furnaceman who has the control of the process, to insure success. The charge containing a quantity of sulphate corresponding to the tungsten in the ore, is put into the reverberatory —Fig. 603—through the workable opening, B, in the arch, and spread by the furnaceman upon the iron bed, A A, of the furnace through the working door, D. The bed is composed of two stout cast-iron plates fixed in the sides of the furnace, and supported near the centre by lines of brickwork; the space left by this arrangement between the plate and solid brickwork forming a flue for the smoke and waste gases of the fire to return under the sole, and thus assist in heating it. C is the fire which at the beginning of the operation should produce a highly carbonaceous flame, with the view of reducing the sulphate of soda to the state of protosulphide, to induce the decomposition of the tungsten and the combination of the acid. For the same purpose some small coal or charcoal is mixed with the charge, the more readily and efficiently to decompose the sulphuric acid of the soda salt. A dull red heat is maintained with all the available openings to the interior of the furnace closed, and a strong reducing flame, till the reduction of the sulphate is effected, occasionally stirring the mixture well till the phosphorescent appearance of the mass disappears. At this stage of the operation a bright oxidizing flame should be produced, to induce the further decomposition of the alkaline sulphide and the formation of the soluble tungstate; after which it is raked out through the hitherto closed aperture, E, to the vault, F. This process has been carried out at the Drake Wall Mine in Cornwall since 1850 with every success.

Fig. 603.



The solution of tungstate of soda obtained by the exhaustion of the fluxed ore with water, is concentrated in iron pans to the crystallizing point, and drawn off into crystallizing vessels, where it remains. In a few days the tungstate separates in beautiful crystals, and which, after slight washing and draining, are fit for market. On concentrating the mother liquors a further crop is obtained. After the ore is exhausted of its soluble salts it is transferred to the floor of the burning house, and the iron and manganese separated by washing or treatment with acids, according to the methods already detailed.

From a consideration of the several operations which ores of tin pass through from their coming to *grass*, as it is called, till they are ready for the smelter, it is supposed that fully a third or more of the quantity of tin originally in the ore is lost. Distributed as the tin must be in minute grains in the stony gangue, it is evident that the latter cannot be so thoroughly broken off from the tin as to leave it isolated, and thus in a state to separate in the several washings. Further, where the tin ore is to the whole of the matter mined as one to thirty or thirty-five, a good deal of tin must be rejected in the tailings of the first process which it has to undergo, *videlicet*, the *spalling* and picking; and analysis of the refuse matters shows that they invariably contain quantities of tin, which loss must be entirely owing to the imperfect, or rather inadequate methods, adopted for disintegrating the ore, and the very slight difference in the low gravity of the gangue which the associated grains of tin ore must occasion, so that such ore will be entirely lost to the miner.

Modern researches show that the loss of tin in the dressing of poor ores is much greater than when richer products are operated upon, in which, however, it amounts to about twenty-five per cent. of the whole quantity. This great loss is attributed to the large amount of tailing stuff produced, and the large body of water made use of in the course of the working. Whilst the existing mode of tin dressing is practised, that loss can hardly be avoided, or at best but slightly lessened. To obtain the whole of the two to three per cent. of binoxide of tin in the tin stuff, the dressing must be based upon chemical rather than mechanical principles. Considering that the loss of tin at present sustained in dressing a hundred tons of stuff averages fully fifty to sixty pounds worth of tin, the recovery of this waste would afford a scope for a partial outlay by which to attain better and more profitable returns.

Many mining companies have of late years substituted crushing mills, such as are sometimes employed in the preparation of copper ores, for the stamping mill, and with great effect and benefit; inasmuch as the crushing mill reduces the ore to a finer state of division, and separates more of the gangue from the hard granules of tin than the stamps, and thereby renders it more easily and freely separable by virtue of its gravity, than when this breaking up is defectively performed. A mistaken notion or prejudice seems to occupy the minds of several miners, with regard to the value of crushers in their line of operations, the more especially if the stuff in which the tin ore is disseminated be indurated slate and the like; for in such cases they seem to be impressed with the idea that the crushers could not work it so well as the stampers. The evidence of many very creditable and experienced persons is directly opposed to this view; and a rational examination of the principles of working with regard to each, would undoubtedly tend to the preference of the crushers. At all events, since the tin miner places so much dependence upon the gravity of the ore as a means by which he can cheaply and expeditiously purify it from grosser and injurious matters, the primary consideration with him ought to be the reduction of the ore to the finest possible state of division. The better this is executed the more completely and expeditiously will the *whole* or chief part of the tin separate in virtue of its density, in a properly ordered system of elutriation.

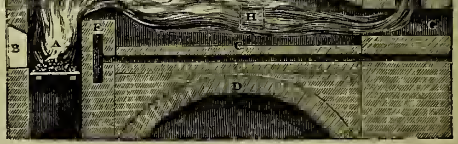
Assaying of Tin Ores.—Although the laws of the Stannery Court do not permit that the product of the tin mines should be sold out of Cornwall before smelting, it happens that the mining proprietors are never the smelters, and so the ores are sold to a few smelters who have the trade in their hands. These buy as cheaply as they can, and according to the declared value of the ore as ascertained by assay. Hence, as in the case of copper, the ores of tin are always submitted to this test to find their value, and it becomes a matter of some interest to the miner, as well as the smelter, to be able to control the determinations of recognized assayers, for their own satisfaction and often protection. The operation is very simple, since the dressed ores are generally operated upon, and consequently very little of any other ingredient remains in the substance, excepting the binoxide of tin, and the silicious or other ganguey matter, separable by fluxes. Still, as binoxide of tin forms permanent compounds with silicic acid at a high temperature, it is necessary to use some precautions as well in the amount of flux allotted to the assay, as in performing the reduction in a black lead crucible, or an earthen one well lined with charcoal, and at the highest temperature of the wind furnace. If sulphurous or other alterable bodies be present in the ore, these should be removed by roasting a quantity of the ore at a low red heat, and using a little ammoniacal carbonate towards the end of the operation, till nothing further is evolved. The ore should in all cases be reduced to the finest powder; and after the roasting, if the quantity of silica and stony matter be deemed in too great excess, the assay may be carefully washed in a mortar or porcelain dish, and a large quantity of the impure matters thus removed. The heavy deposit of tin ore may then be dried and assayed in the following manner. If the ore be highly dressed, two ounces of it are weighed and mixed intimately with one-third to half this weight of powdered charcoal or coke, and half an ounce of ground borax glass; the whole well ground together, and introduced into a black lead pot, or lined clay one, and this placed on the furnace, the heat of which should be maintained at its highest point for fifteen to twenty minutes. At the end of this period, and when the contents of the crucible are in tranquil fusion, the whole is briskly stirred with an iron rod, and then poured out rapidly into an ingot iron mould. When cold, the slag is detached from the button of tin by a few strokes of the hammer, and by the use of the brush; the button is then weighed. Any matters remaining attached to the walls of the crucible are scraped off and ground, then washed, and the particles of metal that may be thus separated, weighed, and the amount added to that of the principal button. Sometimes the flux is composed of equal parts of borax glass and carbonate of soda, and is found to answer very well; so also is the flux compounded of three parts carbonate of soda and one of lime. Of the former thirty to forty per cent. of the ore taken for assay is employed, and of the latter forty per cent. When ores of tin are very poor, so that they necessitate the use of large quantities of flux, very little tin can be reduced from them, on the scale of assay-making, notwithstanding a considerable amount of the metal can be obtained by the treatment of such ores on the large scale. In assaying such ores the better course would be to employ the liquid method of analysis, which will be referred to further on.

Smelting the Ore.—Up to the period of the reign of Charles the First, very little improvements are recorded in the smelting of tin. The remains of ancient workings discovered as existing previous to the above period, appear to indicate that the reduction was carried on in furnaces or hearths scooped out of the ground, and in which a mixture of black tin and charcoal was placed, the necessary intensity of the heat being kept up doubtless by the blast of rude bellows, and the whole operation being similar to the metallurgic process of the travelling tinkers of a few years ago—and perhaps of the present day in Ireland—whereby cast-iron and other refractory metals were readily melted and cast into shapes, such as smoothing irons, *et cetera.* Remains of such furnaces are of frequent occurrence in Cornwall and Devon, and are called *Jew houses.* One of these smelting forges lately discovered beneath a stratum of bog, twelve feet thick, at Redmoor, contained some tin, peat which had been used as fuel, and furnace scoria, with other remains. An analysis of the scoria from other furnaces in the same locality, and apparently of a more modern date than the preceding, showed the imperfections of the methods of smelting. The following are the results which samples presenting the appearance of thin fragments of bottle glass gave :—

	Centesimally
Silica,	40·60
Alumina,	19·20
Oxide of tin,	22·85
Protoxide of iron,	7·31
Sulphide of iron,	9·04
Lime,	trace
Potassa,	1·00
	100·00

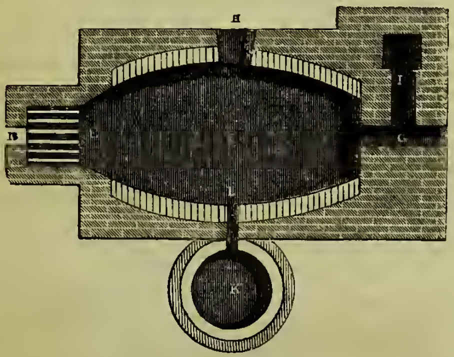
From the other remains found in the site of the slags, *et cetera*, from which the above was taken, it would appear that the date of working could not have been later than about the year 1630. Attempts were made in the reign of the first Charles to employ pit coal instead of peat and charcoal; but the results were unsatisfactory till the first few years of Anne's reign, when improved methods of smelting ores of tin in blast furnaces, by means of fossil fuel, were patented by a Mr. Liddell. At this period, and when the advantage of fossil fuel above peat and charcoal began to be recognized, the invention of the reverberatory furnace soon followed, in which forms of furnaces tin ores have hitherto, but with slight modifications, been smelted.—*Records of Mining and Metallurgy.*

Fig. 604.



Figs. 604 and 605 are a plan and section of the smelting furnace at present employed in the smelting of tin ores. In these figures, a is the fire supplied through the door, b; c is the bed of the furnace, constructed of fire-brick, and supported by the arch, D, having a passage for cold air beneath it, and in the bridge, E, of the furnace, to prevent the overheating of the mass of brickwork in the bed. The charging door is seen at H, and G is the opening through which the charge is worked in the furnace; F is a draught-hole temporarily opened whilst the slags are being skimmed off the metallic bath, and I is the flue leading to the chimney. The ore, which generally averages from sixty to seventy-five per cent. of metal, or, as estimated by the tin assayers and smelters, twelve to fifteen parts, in twenty of ore, is mixed with twelve to eighteen per cent. of powdered anthracite coal, and twenty to twenty-five hundredweight, or a little more, of this mixture, taken for the working charge in the ordinary sized furnace; a small quantity of lime or powdered fluor spar is added in proportion to the amount of silica contained in the material. The whole is shovelled in at the charging door, and spread through this and the working door; after which both doors are closed, and the fire is urged for a period of six to eight hours, gradually increasing in intensity. At the end of this time the ore is well rabbled and mixed by the furnaceman through the hinder door, with the view of bringing the unreduced portions of ore still remaining, within the influence of the heat, and reducing flame from the fire, and the unconsumed carbon of the charge, and likewise of allowing the separated metal to collect into a bath. For a second time the doors are closed, and the interior is allowed to regain its high degree of heat, somewhat reduced during the working of the mass. After a short interval the furnaceman throws some moist slack on the surface of the fused mass in the furnace, and then commences to draw out the top layers of scoria through the working door, to the extent of three-fourths, or thereabouts, of the entire quantity. Whilst this part of the work is being proceeded with, it is customary to open the draught-hole, F, so as to allow the gases to ascend and leave the interior of the furnace partially exposed to the examination of the furnaceman. The above quantity of scoria, if skimmed off with care, contains no metal worth further search, and therefore it is thrown away. The portions which are afterwards drawn out, however, are separated into two classes; the first and largest portion is set aside to be stamped, in order to separate the globules, or *prills* of metal diffused through it to the amount of five per cent., or nearly so; and the second, or final skimmings from the metal in the furnace, are reserved to be melted with a succeeding charge of metal or refuse products, when not only the particles of metal are recovered, but also the tin in the state of binoxide contained in it. When the metallic bath is cleaned in this way, the clay plug hitherto closing the gutter, L, leading to the cast-iron pot, K, is removed, and the tin allowed to flow into the latter. The metal rests here for some time; meanwhile a fresh charge is introduced into the furnace; after which all the apertures are closed as before, and the fire kept up, as already stated. After the metal has remained in the pot sufficiently long to permit the slag and other impurities to rise to the surface, these matters are skimmed off, and the tin is ladled out into cast-iron moulds, each capable of containing about three hundredweight.

Fig. 605.



The tin so procured always contains a certain amount of impurities, the greater when less care has been exercised in the dressing of the ore. These are generally iron, lead, and some other bodies, according to the nature of the accompanying ore, such as copper, tungsten, arsenic, and cobalt. To separate them, however, it is necessary to submit the crude tin to either of two operations—the one, a process by which the more fusible tin is sweated out at a low temperature, and called *liquation;* the other, a *boiling* or *tossing* of the metal, by which portions of it, by its extended exposure to the air in this operation, are converted into oxide; and being in this state agitated with the body of the metal, the oxygen is transferred to the more oxidizable metals, which are thrown off as a scoria, and can be removed by skimmings.

For the liquation, the smelting reverberatory above described, or one similarly constructed, may be used. The blocks of tin are loosely piled upon the hearth, and a moderate heat is applied; the excess of pure tin melts at the low heat, and flows out by the gutter to the receiver, leaving in the furnace an alloy richer in impurities, and therefore, owing to the more refractory nature of the alloyed metals, requiring a higher temperature for melting it than the purer tin. As the progress of heating crumbles and melts the blocks of tin, fresh ones are supplied till about five or six tons of metal have run out to the cast-iron receiver, wherein the second operation is conducted. This receiver is so arranged as to admit of being heated with the view of aiding in the more ready separation of the contaminating ingredients during the boiling or tossing.

The purification by boiling is analogous in principle to the *poling* practised in refining copper, though differing in detail. In the case of copper, the gases eliminated from the wood—watery vapor principally, and some carbohydrogen—serve to decompose the metallic sulphide left, eliminating the sulphur as sulphurous acid and sulphide of hydrogen; whilst in that of the purification of tin, the metal abstracts oxygen from the steam similarly generated, and the oxide of tin thus partially produced, reacts upon the particles of alloyed metals more oxidizable than itself, and eliminates them as oxide, being itself reconverted to the metallic state.

The method of procedure with tin is to have a bundle of billets of green wood mounted on a crane erected by the furnace, and overhanging the pot containing the melted metal; this bundle is forced into the fluid mass, and the result is a violent seething, caused by the eliminated gases. A scum forms in which oxide of tin is a constituent; this is skimmed off and retained to be remelted with a fresh charge, or with the scoria produced in the first reduction. The action of the wood is renewed, and the scum removed, till by a test applied to the metal it is judged sufficiently purified.

Instead of using wood, the process of *tossing* may be practised with the same effect; that is, the metal is taken up in ladles and allowed to fall from a certain height into the caldron; in this case a scum is formed, and is removed in the same way as stated till the metal is deemed pure. The time occupied in the purification averages about five hours; one hour is devoted to the liquidation, three to the boiling or tossing, and one to the subsidence of the metal after it has been thoroughly cleaned by the repeated skimming. During this final hour the metal disposes itself into three qualities of tin: the purer and more fluid metal constitutes the top layer, which is carefully cast or ladled into the moulds, and set aside as grain tin; the middle, which is not so pure, is likewise removed to moulds and retained as common tin; whilst the third portion is returned to the furnace to undergo liquation a second time, to purify it from the greater part of the vitiating ingredients.

The manner of testing the quality of the metal is as follows:—The refiner takes a small ladleful of the melted metal, and having cleaned it by stirring and skimming, casts it into a stone ingot mould, and as it cools, he closely observes its appearance. If it remains bright and clear, full and rounded on the sides, until quite cold, it is sufficiently pure to be classified as grain tin; if the metal, though bright, should not remain so full and rounded at the sides, and if at the moment of solidifying a frosted crystalline appearance shoots from the centre out to the sides, the tin is accounted as second class or common tin; and in the third place, if the metal assumes a slight yellowish appearance, and the crystalline stria appear much sooner, covering the whole of the surface, it is of the third class, and must be repurified by liquation, *et cetera.* The creaking sound emitted by the ingots when bent, is likewise a test which shows the quality of the metal, for this is much greater in proportion to the purity. In tin-smelting works, one day a week is usually devoted to the purification of the crude metal from the reduction of the ore.

The matter remaining in the furnace after the liquation of the tin, is melted at a higher temperature, and run out into another pot, whence it is cast into moulds. This, with the metal washed out from the rich slags after stamping, and the skimmings of scoria, as well as those produced in the refining pot, are resmelted, and the metal which results carried through the same course of operations detailed above. Finally, there remains in the pot a bright brittle alloy, having a crystalline fracture and so surcharged with foreign metals that it is cast aside as not worth the expense and trouble of purification.

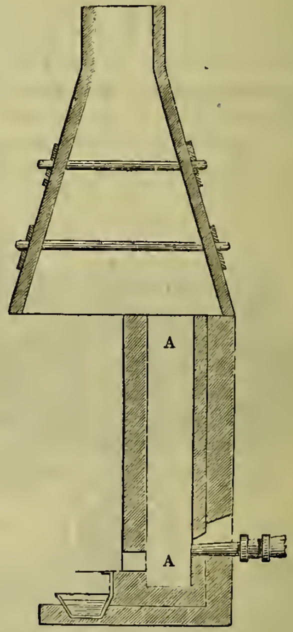
The following is the composition of the three qualities of tin obtained by the preceding operations, according to BERTHIER's analysis:—

	Centesimally.		
	Ordinary Tin.	Common.	Bad
Tin,................	99·76	98·64	95·00
Copper,............	·24	1·16	3·00
Lead,...............	—	·20	1·50
Iron, ...	trace	trace	—
Arsenic,............	trace	trace	trace
Loss,...............	—	—	·50
	100·00	100·00	100·00

The consumption of fuel for producing one ton of tin is reckoned in the Cornish smelting works at a little more than a ton and a half, sometimes thirty-five hundredweight, and the loss of tin in the process amounts to about five per cent.

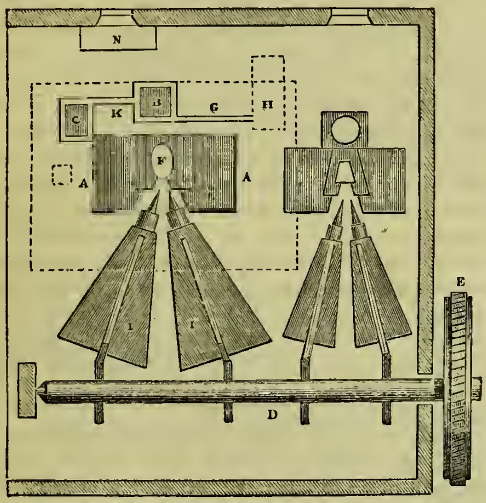
German Method.—In the tin-smelting establishments of Altenberg, *et cetera,* instead of the reverberatory, a small blast furnace is used for the reduction of the ore. Figs. 606 and 607 are a plan and elevated section of this furnace; its height from the hearth to the throat, by which the mixture of ore and fuel is inserted, is fourteen feet. The body, A A, is constructed of large blocks of granite or of coarse-grained porphyritic syenite, and the sole or crucible is formed of a block of the same material hewn to the proper shape, with a fall to the breast of the furnace; but sometimes it is constructed of very refractory fire-bricks, lined with a mixture of charcoal and fire-clay well rammed down. A channel from the furnace leads into a basin, B, from which the slags flow down an incline, G, to the water

Fig. 606.



cistern, H, where they are cooled, and the tin by another conduit, K, flows into the vessel, C. The blast is supplied by the bellows, I I, through the tuyere opening, O. The furnace is surmounted by a dome which serves to carry off the vapors, and as a depositing chamber for the particles of ore driven out of the furnace by the blast. The shaft, D, is turned by the cog-wheel, E, in connection with a shaft from a water-wheel or steam-engine. The small furnace, the parts of which are similar to the preceding, is employed for resmelting the slags produced from the larger furnace. The furnaces are slowly dried after their construction, and then charged with scoria and fuel, and the blast slowly set to work, so as to fuse the more vitrifiable portion, after which the heat is increased till the temperature is raised to the working intensity. The ore, mixed with the reducing agent, and other flux, when necessary, is now charged portionwise, and the smelting proceeded with. At the end of four hours the metal begins to flow. As the slags collect in the basin at the face of the furnace, they are skimmed into the water cistern, and when the metal accumulates so as to nearly fill the basin, it is allowed to flow into the outer one, C, whence it is cast into moulds of varied dimensions. Much of the same practical knowledge is required in the management of this furnace; as has been pointed out under the smelting of copper ores in the blast furnace; for the length of the nozzle formed of the slags, on the end of the tuyere affects the working, and the charge must be regulated accordingly.

Fig. 607.



It is affirmed that the tin reduced in the blast furnace is purer than that smelted in the reverberatory; but the loss of metal and the consumption of fuel is much greater; and these disadvantages have led to the abandonment of the blast furnace in England for the reduction of tin. Smelting by the use of the blast involves a loss of metal averaging fifteen per cent., and a consumption of fuel amounting to three tons of coal for every ton of metal reduced.

Tin is sent to market as *block tin*, in blocks of three to half a hundredweight, and which are cast, as stated in the foregoing, in strips two feet long, one inch wide, and half an inch thick, being so cast in moulds of white marble; and in the form of *grain* tin; the last being produced by heating large blocks of the metal to nearly its melting point, and while in this state, dropping it upon a hard body from an eminence, or striking it with a heavy hammer—in either case, the mass is shattered into long crystalline fibrous columns.

USES OF TIN.—The principal uses of tin are for the manufacture of various alloys which are largely used in the arts, such as bronze, bell-metal, solder, *et cetera;* for making *tin plates*, or rather iron plates, alloyed with the metal; and for preparing tinfoil, whilst its compounds are employed for pottery, in glazes, and colors; and in cloth-printing, as mordants of great value and importance. The reader will find the account of bronze under COPPER, Vol. I., page 534, and of solder, usually compounded of two parts of lead and one of tin. Tin-foil is manufactured similarly to lead-foil, by passing slabs of it backwards and forwards under a pair of rollers; the temperature of the metal being raised occasionally, or maintained throughout, at 212°. The production of tin plates is one of the principal, if not the principal application of tin, and as such this manufacture will be described more in detail.

MANUFACTURE OF TIN PLATES OR SHEET-TIN.—As the superior quality of tin plates depends almost entirely upon the goodness of the iron which constitutes their basis, and the care taken in its preparation, it will be necessary, from the importance of the subject, to dwell at some length upon this part of the process.

The pig-iron selected for the manufacture is generally that known as *red short;* but other varieties may be used, the iron being converted during the purification into plates, the essential qualities of which are great tenacity and toughness at ordinary temperatures. Iron from hematitic ores mixed with other pure ores of the coal measures, answers all the required ends. It has an average composition corresponding with the following samples, containing centesimally :—

	I.	II.	III.	IV.	V.	VI.	VII.
Carbon......	3·47	3·70	2·37	3·42	4·23	3·27	—
Silicium....	1·40	1·33	0·81	1·63	0·49	1·03	1·55
Sulphur....	0·10	0·02	0·54	0·15	0·37	0·04	0·05
Phosphorus	0·60	0·12	0·26	trace.	0·36	0·38	0.18
Iron......	94·43	94·93	96·02	94·80	94·55	95·28	—
	100·00	100·00	100·00	100·00	100·00	100·00	—

Tin plates are divided into two classes, and known by the terms *charcoal* and *coke* plates, owing, in the first place, to the nature of the fuel used in the preparation of the plates before tinning; but, more particularly at present, these names serve to distinguish the goods manufactured by entirely different methods. Charcoal tin plates were the first that were made, and they have been accounted the best. The iron for these plates is rendered tenacious and workable by the aid of a charcoal refinery through which the pig-iron, is passed; and that for the *coke* tin plates is prepared by the ordinary method of puddling and rolling, as described under the article Iron. It will, therefore, be unnecessary to revert to the latter; and so far as the mere coating of the prepared plates is concerned, the description to be given will answer for both. To convert the iron into charcoal tin plates, it is necessary to refine it in a shallow furnace called a *refinery*, the sides and bottom of which are formed of hollow, but very massive blocks of iron, through which a stream of water is kept continually flowing, to protect them from the intense heat of the melted charge. This furnace is of a rectangular shape being four feet long, two and a half wide, and one and a half deep. On one side are three tuyeres for the admission of blast; and these are sometimes round, sometimes oval, the transverse diameters of each in the latter case being 1·15 inch, and its conjugate one inch; they are placed about a foot from the bottom of, and project considerably into the furnace, inclining downwards at a sharp angle. These, like the block forming the furnace, being subjected to a powerful heat, are protected by a coil of iron pipe, twisted round them, through which pipe a stream of cold water is kept always passing. Occasionally, refiners are constructed of larger dimensions than that described, having tuyeres at both sides; these are usually called *double refiners.* A coke fire is made in the space between the *water-blocks* or hearth, and the blast turned on till the whole is thoroughly ignited; a fresh supply of fuel sufficient to fill the space to the height of three feet above the tuyeres, is then heaped on; and, after a few minutes' blowing to increase the heat, a charge of pig iron, varying according to the size of the furnace, and generally reduced for the first time, is put on; the coke is soon ignited, and the metal attains a red heat quickly, after which, the heat being still kept up with fresh supplies of fuel, the metal gradually sinks, and as it comes into contact with the blast, it melts and drops to the bottom of the hearth. The downward direction of the tuyeres causes the stream of air to impinge on the highly-heated liquid iron, and thereby renders the temperature of the latter intense, owing to a portion of the metal being oxidized, as well as the silicium, sulphur, *et cetera.* All these products of oxidation are thrown up to the surface, and form a considerable amount of scoria or cinder that considerably aids in the depuration of the metal. Generally, in an hour and a half after charging, the furnace is fit for tapping; the metal is run out into iron moulds prepared for it, and which are protected against melting by a stream of cold water that flows beneath them. These moulds are sometimes flat, in which case the metal is called *plate metal.* In South Wales, however, it is more usual to run the liquid iron into moulds, consisting of three longitudinal grooves or channels, having raised dams or *stops* at the distance of every five feet, to facilitate the breaking of the metal. As it runs out of the refinery, it is covered by minute, intensely brilliant, and very numerous coruscations arising from the combustion of a portion of the fluid; these coruscations are accompanied by a brown smoke—a phenomenon also of the Bessemer process. As the metal runs out, the slag or cinder, which is likewise highly heated, flows after it, forming a layer on the surface of the moulds, and thus prevents further combustion of the iron. Cold water is now thrown on the whole, when the cinder at once froths up and solidifies on the surface, causing it to assume a spongy appearance that distinguishes it from all other kinds of slag formed in the several processes for refining iron. The first charge worked in the refiner is less than the following ones; but the normal weight, about twenty-two hundredweight, is attained after the third. The number of charges worked every twenty-four hours is eleven or twelve; and the weight of refined metal produced in a week of six days and five nights averages sixty tons, for which about seventy-two tons of pig are required. The produce varies, however, according to the skill of the refiner, the quality of the material used, and the nature of the required product.

Good refined metal has a bright silvery-white fracture, and a radiated structure, the rays springing and diverging from the lower side; it emits a clear metallic sound when struck, is very brittle, with its upper surface indented into a kind of honey-combed structure, the depth of the indentations being dependent on the length of time that the iron has been subjected to the blast. About half an inch deep of honey-comb is considered to indicate the state of refinement best suited for the making of tin plates. It is somewhat curious that, as the refined metal graduates into steel, the honey-comb leaves the face or upper side, and tends to the centre of the horizontally-cast ingot.

The effect of the refining, as before stated, is the removal of the silicium, and of a portion of the sulphur and phosphorus contained in the crude material. The silicium is converted by oxidation into silicic acid, which combines with a portion of the iron oxidized, and forms a fusible slag or cinder on the surface of the metallic bath. The sulphur is converted into sulphurous acid gas, and passes off as such, and the phosphorus into phosphoric acid, which is retained in combination with the oxide of iron in the slag. Very little of the carbon, contrary though it be to the preconceived opinion of iron-masters, is removed during the preceding course of refining, as is sufficiently proved by analysis, and will be evident from an examination of the annexed table showing the composition of different specimens of refined iron:—

	I.	II.	III.	IV.	V.
Carbon	3·070	3·250	2·000	3·200	—
Silicium	·630	·500	·540	·550	0·32
Sulphur	·157	·575	1·250	0·870	0·18
Phosphorus	·734	·835	·985	·920	·09
Manganese	trace	—	·056	trace	·24
Insoluble residue	·530	·050	—	—	—
Iron	95·140	96·300	94·255	95·000	—
	100·261	101·510	99·046	100·540	—

Although the above samples were not made from the cast-irons, the analyses of which have been previously given, yet they serve to prove what has been just stated regarding the chemical changes that take place in the fire. By comparing the results of the two series of analyses, it will be found that only one-seventh of the carbon is separated at the same time that one half of the silicium is removed. On the other hand the sulphur and phosphorus are in larger quantities in the samples of refined than in the crude metal, showing at least that very little if any of these elements are separated, or else that the crude material submitted to the process was of very bad quality. It appears, however, that fully one-third of the content of phosphorus and somewhat more than this amount of the sulphur, with nearly the entire silicium in the pig, are thrown off, the carbon suffering only a slight diminution.

The following analysis shows the nature of the refining cinder thrown off during the operation:—

Silica	23·76
Protoxide of iron	61·28
Oxide of manganese	3·58
Alumina	7·30
Lime	2·41
Magnesia	0·76
Sulphur	0·46
Loss	0·45
	100·00

Besides the foregoing method of refining, two others, long followed to some extent, are known—the first is a modification of **BESSEMER'S** process, and the second is one patented by Mr. **PARRY** of the Ebbe Vale Iron Works. In the first, the action of the blast is stopped when the melted iron has passed to the state of refined metal; but as the iron prepared in this way has never been used in the manufacture of tin plates, it will be needless to prolong the description. The metal purified from common Welsh pig contains centesimally—

Sulphur	1·040
Phosphorus	1·128
Silicium	trace

PARRY'S process differs considerably from those referred to. According to it the melted pig-iron is run at once from the blast into a reverberatory furnace very similar to that used in puddling. On each side of this are three or four small tuyeres pointing downwards to the hearth, through which superheated steam is forced at high pressure; they are so arranged that the current will cause a gyration of the surface of the metal, and thereby expose fresh surfaces of it continually to the blast. The action produced is similar to that effected in the ordinary refinery—the oxygen of the steam, together with that passing over the grate, causes the necessary oxidation, and, therefore, the formation of cinder as before. It should be observed that in this process a considerable quantity of rich cinder, such as hammer slags, mill-scales, *et cetera*, is added to the melted metal in the refinery, and the result of the union is that much of the iron in those cinders is reduced and converted into refined metal, so that in most cases the product equals the amount of metal introduced from the melting furnace. This result is brought about by the carbon in the molten mass acting upon the rich slag, and reducing the iron in it to the metallic state simultaneously with its own consequent conversion into carbonic oxide, in which form it escapes; hence the cinder produced, though abundant, contains less iron than that formed under ordinary circumstances, namely, only thirty per cent. The hydrogen, likewise, has an important effect; it acts upon the sulphur and phosphorus of the metal, and converts these into sulphide and phosphide of hydrogen, which, like the carbonic oxide just mentioned, escape. The metal is thus rendered much purer, and well adapted for the manufacture of tin plates.

The next operation is the refining in the charcoal fire, in a furnace similar to the old blooming fire used in this country previous to the introduction of the puddling process. It consists of a shallow hearth eighteen inches deep, twenty-eight by thirty-two inches at the upper part, and twenty by twenty-one inches at the lower. On one side is placed a ⌓-shaped tuyere protected, like the others spoken of, seven or eight inches from the bottom. The tuyere side and that opposite to it are occasionally constructed of *water blocks*, but generally of dry iron plates. Charcoal is the fuel used, and, in recently-constructed works, the products of combustion pass through a chamber at the back of the fire, and there raise the charge of metal to a red heat previous to its introduction into the fire. The refined metal being thus heated, it is drawn down into the fire, the whole of the hearth of which has been previously filled with charcoal, so as to completely cover the tuyere; more fuel is then added, and the blast turned on. In twelve to fifteen minutes the metal begins to melt, and at the end of forty-five minutes it is completely molten and lies on the bottom just under the blast. The workman now proceeds with a bar to break it up and raise it into more immediate contact with the blast, exposing it by this operation on all sides. A small quantity of cinder is thus formed, after which it is tapped off and another charge of heated metal let down and treated in the same way till the whole coheres into one mass. This occurs about an hour after charging. At this period it is usual in most tin works to add a bundle of shavings, cut from the edges of the *black plate* presently to be described. This new addition is very quickly blended with the previously formed *loops* of iron; so that in about ten minutes after adding it, the whole will be in one mass at the bottom of, and nearly filling, the hearth. During this part of the work very little fuel is required, merely sufficient to cover the iron. It is now taken out of the fire and freed from scurf and cinder as much as possible, all the pieces thus separated and the scales from the *helve* being taken back to the fire for the next charge. The loop is first hammered into a roughly cylindrical bloom and then into a flat irregular shape of about two inches thick. In this plate are cut deep grooves parallel with one another, and six inches apart. It is then thrown into cold water to cool, and broken into the rectangular pieces previously roughly indicated by the parallel grooves or notches. The charge of refined metal taken in this operation is about two hundred and seventy pounds, and the loss is such that to make one ton of *charcoal-refined*, or *stamped* iron, as it is sometimes called, requires twenty-two hundreds of refined metal and about eight bags—equal to one hundred and twenty cubic feet—of charcoal. The number of charges worked off in the twenty-four hours averages eighteen.

The effect of this process is to continue, and, in a great measure to complete, the purification begun in the previously described process, the result being, in fact, crude wrought-iron. The fresh fracture presents very large, bright, and flattish crystals, of a silvery color; and its fitness for the subsequent processes is mainly judged of by its appearance, and by the manner in which it breaks under the hammer. In fact this is almost the most important operation in the whole series which constitute in the aggregate the manufacture of tin plates; and if it be not properly conducted all subsequent treatment results in loss and vexation. The chemical reactions that are effected are a continuation of the carbon in the iron, and the separation of the sulphur and phosphorus, with other impurities, by the same agency. The similarity between the two methods now treated of and the BESSEMER process must be apparent to every one; the only difference being the presence of carbon in both, the plans described, to prevent the excessive oxidation and loss resulting from the patented method of BESSEMER.

Fig. 608.

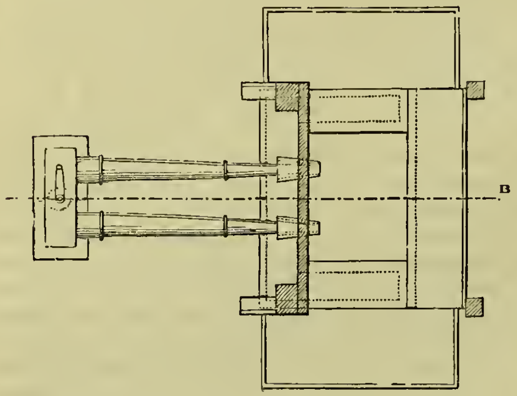
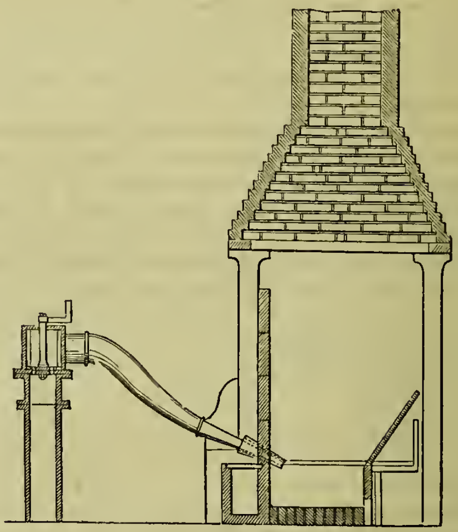


Fig. 609

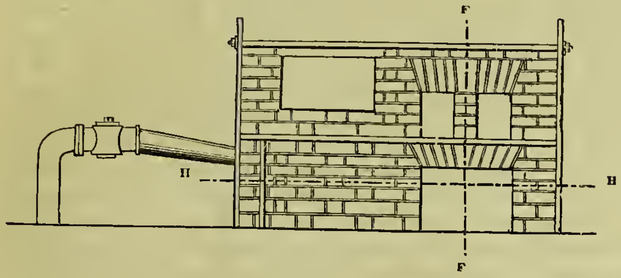


In some works it is usual to run the fluid metal direct to the charcoal fire, and this practice certainly economizes fuel, as all the caloric absorbed in raising the refined metal from its cold state to the melting point must be saved. When this is the case, the refinery is made very much smaller than that before mentioned, and is charged with only six hundredweight of pig, which, when refined, supplies two charcoal fires. This kind of furnace is often called a *running out* or *dandy fire*—Figs. 608 and 609, the former a plan and the latter a vertical section on the line A B of the plan—and is now very generally used. Instead of using charcoal in these fires, it is customary in some localities to use a very light, spongy coke, and this difference gave rise to the terms *coke* and *charcoal* plates, though at present the former name is applied to puddled iron. Coke of this nature has received great attention recently; and there can scarcely be a doubt of the fact that if this fuel is carefully manufactured from a proper and pure coal, and finished by the action of steam while hot, according to a process lately patented by Mr. R. S. ROPER, it forms as good a fuel as charcoal; and that tin plates made in this way are not to be distinguished in appearance or quality from the charcoal plates.

The charcoal iron next undergoes a reheating and welding process. One of the rough irregularly oblong pieces, weighing about thirty pounds, is laid on a flat plate of iron with a long handle, called the *portal* or *staff*, and placed in the *hollow fire*—shown in elevation in Figs. 610 and 611—where it is raised to a soft welding heat previous to reducing it to blooms. Fine sand is thrown on the surface of the metal from time to time, to remove the oxide or *scale* formed on it by the action of the heat and the free oxygen entering the fire, which scale, if left on it, would interfere with the proper welding. Afterwards it is carried to the hammer and beaten into a bloom, as stated above, and welded to the portal; this is again returned to the hollow fire, three other pieces of the charcoal iron being previously placed upon it, and after its temperature is raised as before, again worked into a bloom six inches wide and two thick under the hammer. This is cut nearly in the middle, and the parts doubled up on one another—reheated—rehammered into a bloom six inches by four—then taken to the hollow fire to be reheated—cut off from the portal—and finally passed several times through a series of grooves in a pair of rollers till it is reduced to a bar or slab six inches wide and half an inch thick. These dimensions, however, vary slightly particularly the thickness, according to the size and gauge of the plates afterwards to be rolled from them.

The *hollow fire* alluded to is one of the earliest applications of the gas flame to metallurgical purposes, having been in use upwards of seventy years, previous to which an earlier form, was used, and is still employed in the charcoal forges of North Lancashire; in this early form the iron was surrounded by a dome of ignited fuel, the flame from the combustion of which produced the necessary heat. In the present modification, the furnace is of bricks, and in three divisions—at one end is a space containing ignited coke, into which a continued blast of air is blown by two tuyeres; the flame thus produced passes into the middle position, where the iron to be heated is placed; and the third or middle-end division is intended for the partial heating of said iron by the waste heat, preparatory to its being introduced to the middle division.

Fig. 610.



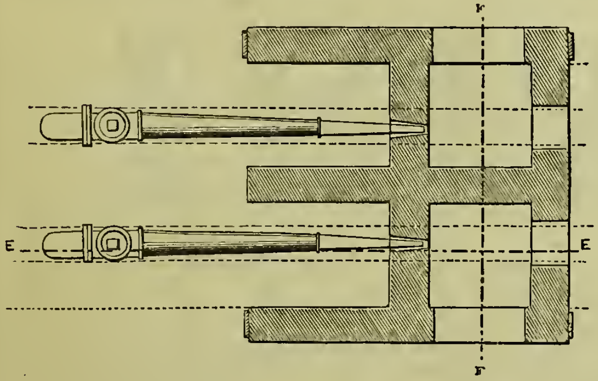


Fig 611.

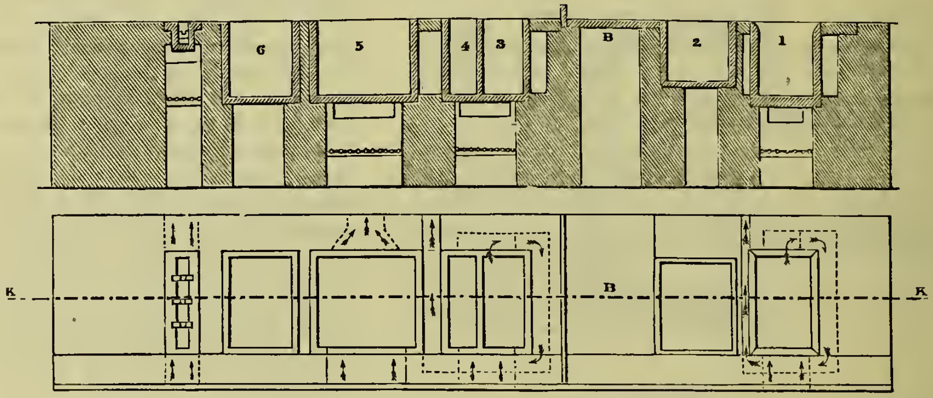
The operation just described is a most wasteful one, involving a loss of three or four hundredweight of iron per ton of bars made; and this is the more striking as the material operated on is wrought-iron. It is owing chiefly to the numerous beatings to which the metal is submitted, and the large volumes of oxygen that enter the furnace through its numerous openings, and possibly also the excess of blast blown into the coke. The latter cause of loss might be avoided by care on the part of the workmen; but it is to be feared that the waste can be but slightly diminished while so many apertures for the entrance of air are allowed to exist. To remedy the evil many experiments have been made to avoid this process altogether, but hitherto without leading to the adoption of any advantageous plan. Mr. William Daniel patented a mode of dispensing with the operation, but it is only partially carried out, though it was in a great measure successful. He directs to put the lump from the charcoal refinery under the hammer, where it is *nobbled* or hammered into a roughly cylindrical bloom, then passed through the rolls and reduced to a bar six inches square and about two feet and a half long. This bar is then either cut or sawn into pieces six inches long, and rolled endwise to give a bar six inches wide, two and a half thick, and twelve long; afterwards this billet is heated in a small balling furnace, and rolled down to a bar a quarter of an inch thick, eleven wide, and about six feet long. This is at once taken to the tin plate mill and made into plates.

It is necessary to revert here to the *coke tin plates*, which name, as already stated, was originally applied to them in consequence of the kind of fuel used in the second refining operation. At present it means those produced from puddled iron rolled into bars similar to those described in the preceding, and called *tin-plate bars* or *tin bars*. In all the subsequent processes the same *modus operandi* is followed, whether the tin bars be made from the puddled or from the hollow fire iron—charcoal tin bars; therefore the following description of the process to which the bars are subjected, previous to, and up to their conversion into tin plates, applies equally to both kinds.

The bars are taken to the shears, where they are cut to proper lengths in accordance with the size of plates to be made—thus for No. 1 c plate, which is 13¼ × 18—see table, page 1071, the length of piece will be fifteen inches, the exact dimensions of it being 15 × 6 × ⅜ inches. These short pieces are then placed in packs in a reheating furnace, having a very slow draught, and there raised to a dull red heat; they are next passed singly breadthwise several times through a pair of narrow flat rolls; reheated, and then drawn out across the original fibre to a length of five feet and a half. Such plates are then doubled down, and the ragged ends produced in the rolling shaved off. After this they are returned to the furnace and heated to redness, passed through a pair of rollers similar to the last, but more carefully turned to give them a very smooth surface, and there rolled till each is drawn out to five feet—this virtually being two plates five feet long united at one end. The combined plates are again doubled, the waste end sheared off, returned to the fire, and when heated repressed under the rolls till they are extended to about forty-three inches, the entire forming four plates. The operation of doubling, heating, and rolling, is continued sometimes till the original plate is reduced to eight and even sixteen plates, all passing under the rollers as one. It is to be observed, that great care is required to prevent the plates from being welded either by a too high heat, or from a neglect of partially separating them from time to time, by the rollers. In this way the original piece of bar is rolled into four sheets, each forty-three inches long by fifteen wide. The plate of four, eight, sixteen, or thirty-two thicknesses, or sheets, is then taken, unopened, to a pair of shears, which cut off the two ragged longitudinal edges at one stroke, and at such distances as to determine the length of the tin plates; they are then cut across by the same machine at distances equal to the intended breadth of the same; and thus are obtained four, eight, sixteen, or thirty-two plates in each division of the proper dimensions, still so closely pressed as apparently to be but one. They are next separated, and all the defective ones picked out; such, for instance, as contain streaks of dirt pressed into them, those welded together, and the like, and the choice ones, called in this state *black* plates, are taken to the *pickling* room. Here they are immersed in a bath of warm dilute oil of vitriol during fifteen or twenty minutes, to remove the scale of oxide on them. The acid leaves them with a clean dullish-grey metallic surface; and to assist the action of the acid in this respect the plates are rubbed with sand and water, and afterwards washed, when they are ready to be sent to the *annealing* house.

It will be readily understood that, after the repeated rollings and the immense strain the plates have been subjected to, they are at this stage very brittle; and therefore, if turned in this state, they would not bear to be hammered into the multitudinous and complex shapes required in commerce. To remove this defect, the process of annealing is had recourse to, and the work is conducted thus:—The plates are placed to the number of about eighteen hundred—for common sizes—in piles, within a cast-iron box about two feet square, the lid carefully luted on to prevent air entering, and then placed with several similarly filled ones in a stove constructed very much in the shape of a reverberatory furnace, but considerably larger, and having its bed on a level with the ground. The fire-bridge being tolerably high, the flame from the grate rolls slowly over the boxes, and raises them gradually to a cherry-red heat, at which temperature they are maintained during twelve hours, and then withdrawn. When quite cold, the covers are taken off, the plates taken out, carefully examined, and sorted. If the heat has been too high, some of the plates will be found adhering to one another; if too mild, they will not be much improved by the operation, and if air should have entered, they will be either partially or completely converted into scale or oxide of iron. After being subjected to this process, the plates will have a deep plum-color bloom on their surfaces, due to a very thin film or coating of oxide that has formed upon them. They are now passed three times through a pair of rolls similar in form to those previously described, but with which great pains have been taken, to make their surface hard, smooth, and brilliantly polished. Then rolls are placed in close proximity, so that the plates passing between them are subjected to a very great pressure, but not sufficient to enlarge them. After having been thus *cold rolled*, as it is termed, the plates are extremely smooth, and possessed of a lustrous and dappled appearance, still owing to the thin oxidation. One effect of this rolling is to make the plates brittle once more, and therefore to necessitate a second annealing, which is performed in the same way as the preceding; but the heat is milder, and the time reduced to five or six hours. Another sorting follows, when the good plates are sent to the *tin house*, and the defective ones returned with the shearings of the *black* plates to the *charcoal fire.*

Fig. 612.



In the tin house the plates are again *pickled* in a warm but more dilute bath of oil of vitriol than that already used, during ten minutes, then removed and well rubbed with sand and water, to detach all dirt and scale. They should now have a smooth, perfectly clean, greyish metallic surface, in which state they can be kept in cold water without injury for some time, and are ready for the *tinning*.

Tinning.—The apparatus or *stow*—Fig. 612—for this process consists of a series of baths set side by side, for the convenience of the workmen, each bath having a fire beneath it, to keep the materials they severally contain in a fluid state. These baths or *pots* are six in number—namely, 1, the tinman's pot; 2, the tin-pot; 3, the washing or dipping pot; 4, the grease-pot; 5, the cold-pot; and 6, the list-pot. The tinman's pot is full of melted grease, and into this the plates are immersed and left till all moisture upon them is evaporated, and they become completely covered with the grease. It is about two feet long, fifteen inches wide, and twenty inches deep. From the tinman's pot the plates are removed to the tin-pot, and plunged into the bath of melted tin, protected with a layer of grease which it contains, and remain in it for about twenty minutes. This pot has a capacity of 22 × 18 × 16 inches. In the first dipping the alloy is imperfect, and the surface not uniformly coated, consequently the plates are removed to the dipping or wash pot, which is divided into two compartments. The first immersion takes place in the larger division, which contains molten tin covered with grease like the last, and here the plate is left sufficiently long to make the alloy complete, and to separate any superfluous tin which might have adhered to the surface. The workman then takes out each plate separately to a table between the wash-pot and the grease-pot, and wipes it on each side with a brush of hemp to remove any excess of tin; to obliterate the marks of the brush, he dips it quickly into the second compartment of the wash-pot, and then at once into the grease-pot. This second compartment of the wash-pot always contains the purest tin; and as it becomes alloyed with iron, it is removed to the first compartment of the same, and thence to the tin-pot. The grease-pot is filled with melted grease; and great care is necessary to maintain it at the proper temperature. Its purposes are to allow any superfluous tin to run off, and especially to prevent the alloy on the surface of the plate cooling more rapidly than the iron. If this were neglected, its surface would be cracked. After ten minutes' immersion in the grease-pot the plate is removed to the cold-pot, which is filled with tallow heated to a comparatively low temperature. The pots 4 and 5 serve the purpose of annealing the plates, and of cooling them down to a low temperature. The last one in the series is the list-pot, and is a small cast-iron bath kept at a sufficiently high temperature, its bottom covered with tin to the depth of a quarter of an inch. In this the edges of the plates are dipped and left in till the wire of tin, which usually forms on them in the course of the foregoing processes, melts, and is removed by a quick blow on the plate with a stick.

The articles are now tin plates; but before they are sent to market, they undergo some further treatment. Firstly, they are carefully rubbed with bran to clean them from grease and dirt; secondly, they receive another rubbing with a pad of sheep-skin, retaining its wool; and thirdly, they are sent to the sorter, whose duty it is to pick out defective plates, and to arrange the good ones in piles according to their size and quality. They are finally packed in boxes, which are branded on the outside with the marks indicating the size and quality of the plates, and sent to market.

Quality of Tin Plates.—The tests for tin plates are ductility, strength, and color; and to possess these, the iron used must be of the best quality, and all the process be conducted with care and skill. The following conditions are inserted in some specifications, and will serve to indicate the strength and ductility of first-class tin plates:—

1st, They must bear cutting into strips of a width equal to ten times the thickness of the plate, both with and across the fibre, without splitting; the strips must bear, while hot, being bent upon a mould to a sweep equal to four times the width of the strip.

2nd, While cold, the plates must bear bending in a heading machine, in such a manner as to form a cylinder, the diameter of which shall at most be equal to sixty times the thickness of the plate. In these tests, the plate must show neither flaw nor crack of any kind.

The following table exhibits the usual brands and their value in dimensions of plate, number, and weight per box, and may be found useful for reference:—

TABLE OF MARKS, WEIGHTS, AND DIMENSIONS OF TIN PLATES.

Name.	Size. inches. inches.	Number in box.	Weight of box. cwt.	qr.	lbs.	Mark or brand.
Common, No. 1,	13¾ × 10	225	1	0	0	I C
“ No. 2,	13¼ × 9¼	“	0	3	21	II C
“ No. 3,	12¾ × 9½	“	0	3	16	III C
No. 1, cross,	13¾ × 10	“	1	1	0	I ×
No. 1, 2 “	“	“	1	1	21	I ××
No. 1, 3 “	“	“	1	2	14	I ×××
No. 1, 4 “	“	“	1	3	7	I ××××
Common doubles,	16¾ × 12½	100	0	3	21	C D
Cross doubles,	“	“	1	0	14	× D
2 cross doubles,	“	“	1	1	7	×× D
3 “	“	“	1	2	0	××× D
4 “	“	“	1	2	21	×××× D
Common small doubles,	15 × 11	200	1	2	0	C S D
Cross ‘	“	“	1	2	21	× S D
2 cross “	“	“	1	3	14	×× S D
3 “ “	“	“	2	0	7	××× S D
4 “ “	“	“	2	1	0	×××× S D
Wasters, common No. 1,	13¾ × 10	225	1	0	0	I C W
“ cross No. 1,	“	“	1	1	0	I × W
‘ common small doubles,	15 × 11	200	1	2	0	C S D W
“ common doubles,	16¾ × 12½	100	0	3	21	C II W
“ cross doubles,	“	“	1	0	14	× II W

The Editor thankfully acknowledges his obligations to his late talented pupil, Mr. R. S. ROPER, for his assistance in preparing the preceding remarks on tin plates.

ULTRAMARINE.—*Outremer*, French ; *Lazurstein*, German.—This is one of the most beautiful pigments known, and its artificial production is justly viewed as belonging to the greatest triumphs of modern chemistry. It is obtained by isolating the coloring matter of lapis-lazuli, outremer, or lazurstein, mostly brought from China, Thibet, and the shores of Lake Baikal. It is a mineral of indeterminate composition, as will be seen from the annexed analyses—

	Gmelin.		Dann.
Silicic acid,	49·00	....	45·50
Sulphuric acid,	2·00	....	5·90
Alumina,	11·00	....	31·80
Soda,	8·00	....	9·10
Lime,	16·00	....	3·50
Magnesia,	2·00	....	—
Sesquioxide of iron,	4·00	....	0·80
Sulphur,	trace	....	—
Water,	trace	....	—
Chlorine,	—	....	0·40
Loss,	8·00	....	2·00
	100·00	....	100·00

Lazulite often contains scales of mica and iron pyrites. It is found in masses, more or less pure, generally in small volume, fragile, but capable of scratching glass, of granular texture, imperfectly laminated, and almost transparent at its edges. It crystallizes in dodecahedrons, with rhombic faces, but the crystals are rare—specific gravity, 2·50 to 2·96. The hue, which occurs in isolated places, merges from celestial to pure blue and indigo purple. It is usually disseminated in a rock, which contains many other laminated substances, among which is a fine white lazulite. In the *Musée Mineralogique* at Paris are two fine specimens of lazulite, in which is seen the transition from the azure to the white. Tomlinson remarks that the iron pyrites sometimes propagated in lazulite, is of a bright yellow hue, helping to relieve the lustre of the blue, and they have often been mistaken for pellets of gold; in fact, the cause of its intense blue color was long a matter of controversy. No traces could be detected of cobalt, copper, or any other element or compound known to impart an azure tint. The existence of an unknown protoxide of aluminium—Al O—was even assumed as a means of solving the difficulty; and not until ultramarine had been prepared artificially, and the synthetical proof had thus been superadded to the analytical, was it admitted that a blue tint could be produced by the union of three colorless bodies—*alumina*, *sulphur*, and *soda*.

Clément and Désormes published an analysis of this substance in 1806; they admit, of course, the great difficulty experienced in analyzing ultramarine. They regarded it to have the following composition, which is in many respects similar to the results obtained by Wilkens, and subsequently given—

	Centesimally.
Silica,	35·80
Alumina,	34·80
Soda,	43·20
Sulphur,	3·10
Carbonate of lime,	3·10
	100·00

The great cost of ultramarine, and the unparalleled effects which it produces in painting, rendered it most desirable to produce this compound artificially. Chemists were for some time baffled by the discordant results each obtained, and were thereby unable to distinguish which of the ingredients of ultramarine were essential, and which accidental or superfluous.

The first step, says Tomlinson, towards the production of this pigment artificially was in 1814. Vauquelin, in visiting the plate-glass works at St. Gobain, was informed by the director of the sulphuric acid and soda department of the establishment, that, in taking down the soda furnaces a blue mass was found when *grés*—gritstone—was employed in the formation of the sole, but there was no such deposit when the sole was of brick. The Editor has often remarked in black-ash furnaces the production of ultramarine; in fact, all recent analyses of this substance give about one per cent. of this blue pigment. Vauquelin took some of the compound, reduced it to powder, and, washing it, found it was decolored by the mineral acids, with the disengagement of sulphide of hydrogen; that it was not attacked by boiling alkaline solutions, nor destroyed at a red heat. This chemist further states, that though the composition of this artificial product is unlike that of lapis-lazuli, yet he is not without a hope that the circumstance may lead to the production of ultramarine artificially. This observation, and the suggestion founded upon it, appears to have been forgotten for nearly fourteen years. To Gmelin of Tubingen the honor of the discovery of artificial ultramarine is generally said to be due; but, as Tomlinson remarks, if the question of priority were raised, then it must be claimed by the *Société d'Encouragement* of Paris, who offered a prize of six thousand francs for the manufacture of ultramarine. Guimet obtained the prize in 1828, on which occasion he communicated his recipe confidentially to Gay-Lussac.

To prepare the pigment lapis-lazuli, freed from all mechanical impurities, is gently ignited, slaked in water, and reduced to an extremely fine powder. This is now incorporated with a melted paste called *pastelle*, consisting of linseed oil, wax, and resin, and kneaded under cold water. Ultramarine gradually deposits in the vessel as a dark-blue powder, which grows brighter by degrees, whilst the impurities remain entangled in the *pastelle*.

The color thus obtained is of necessity very expensive, from the rarity of the material, and from the tedious and wasteful mode of producing it.

The preparation of artificial ultramarine has undergone many modifications since the experiments of Gmelin. Brunner mixes seventy parts of silica, two hundred and forty of burnt alum, forty-eight of charcoal powder, one hundred and forty-four of flowers of sulphur, and two hundred and forty of anhydrous carbonate of soda, all reduced to an impalpable powder; puts the mixture in a Hessian crucible, and lutes down the cover. The crucible is heated to moderate redness, and kept steadily at that temperature for an hour and a half, and then suffered to cool. If the operation has succeeded, the mass has a loose, half-fused appearance, and a greenish or reddish-yellow hue. If solid, fused, and brownish, the heat has been too high. The mass is taken out of the crucible, and washed till the liquid has no longer a sulphurous taste. The residue, a dark greenish-blue powder, is filtered, dried, mixed with its own weight of sulphur, and one and a half times its weight of anhydrous carbonate of soda, and heated as before. The residue is boiled with water for some time, filtered, and washed till the liquid no longer blackens carbonate of lead. The dried powder is sifted, and submitted to the following final process: — A plate of cast-iron is covered to about the depth of a line with pure sulphur, upon which the compound is sifted to about an equal depth. The plate is then cautiously heated till the sulphur takes fire. The residue is removed from the plate, again pulverized, and resubmitted to the same treatment with sulphur, until the color is found satisfactory.

Pruckner adopts a somewhat modified process. Sulphide of sodium is prepared by igniting sulphate of soda with charcoal powder. This is dissolved in water, some free sulphur is added, the liquid is concentrated, mixed with one half per cent. of sulphate of iron and twenty-five per cent. of a well-tempered clay—the purer and whiter the better—the mixture evaporated to dryness, the residue powdered, and ignited for an hour in a cupelling furnace; when cold, it is extracted with water, the residue dried, powdered, and once more heated in a muffle, when the required tint appears.

A still further simplification is to ignite sulphate of soda with charcoal powder and clay in a crucible, with slight access of air.

Tiremon's recipe for this pigment is the following:—One thousand and seventy-five parts of crystallized carbonate of soda are fused in their own water of crystallization, and the fused mass mixed by stirring, first with five parts of red sulphide of arsenic, then with a quantity of hydrate of alumina, prepared from alum by precipitation with carbonate of soda, and containing seven parts of anhydrous alumina, and lastly, with a mixture of one hundred parts of sifted clay, and two hundred and twenty-one parts of flowers of sulphur. The mass, after being intimately mixed and evaporated to dryness, is introduced into a crucible provided with a good cover, and gently heated at first, in order to expel the remaining traces of moisture, the temperature being afterwards raised to full redness. The mass should cake together without fusing. If the materials have not been properly mixed, the whole will exhibit white spots; and if it has been fused, it is studded with brown ones. After cooling it is roasted, in order to expel the greater portion of the sulphur, then reduced to powder, and washed slightly on a filter with cold water. The bluish-green powder thus obtained is again roasted for an hour or two, with occasional stirring, in covered basins, at a temperature never exceeding low redness. According to **Elsner**, a very small quantity of iron, such as is usually contained in the ingredients, *is essential to the production of the hue*, but excess is injurious. A mixture of one part of clay, perfectly free from iron, with one part of sulphur and two parts of anhydrous carbonate of soda, yields a yellowish mass when ignited; but if a trace of sulphate of iron is added to the mixture, a mass is obtained which is black, green, or blue, according to the degree of heat to which it has been subjected. When potassa is used instead of soda, **Gmelin** states the blue tint is not obtained.

Before the analysis by **Margraf**, the color of ultramarine had been attributed to the presence of copper, but this chemist only found sulphuric acid, lime, and iron; others suspected, naturally enough, the presence of cobalt; others again, hydrofluoric acid. **Klaproth's** results indicated the following:—

Carbonate of lime,	28·00
Sulphate of lime,	6·50
Alumina,	14·50
Silica,	46·00
Sesquioxide of iron,	3·00
Water,	2·00
	100·00

Guyton thought that the coloring matter was a blue sulphide of iron.

Pure ultramarine, according to **Wilkens**, has the composition—

$$2\,(Al_2\,O_3,\,Si\,O_3) + Al_2\,O_3,\,3\,Si\,O_3 + Na\,O,\,S_2\,O_2 + 3\,Na\,S.$$

It should contain, therefore, theoretically—

	Per cent.
Silica,	38·75
Alumina,	26·37
Sulphur,	13·68
Soda,	21·20
	100·00

an assumption which agrees pretty closely with the actual analysis of the purest samples. A variety of substances, such as iron, lime, potassa, magnesia, sulphuric acid, and chlorine, may be present as impurities, and were, in part at least, purposely added by the earlier manufacturers; but they are found to be perfectly unnecessary. The coloring matter appears to consist of hyposulphite of soda and sulphide of sodium. If the firing be conducted in porous crucibles, the coloration of the mass is generally unequal.

Green Ultramarine.—Ordinary ultramarine, on ignition with saltpetre, assumes a green color. Green portions, more or less in quantity, are frequently formed in the crucibles, especially on the first ignition. On repeated heating it passes into a blue tint. Artificial ultramarine is, however, very rarely entirely freed from all traces of the green modification, and hence it is, for the most part, less beautiful than the natural variety.

Ultramarine is readily decomposed by acids, with evolution of sulphide of hydrogen, and total destruction of the color. At a high temperature this effect is even produced by silica, whence the unfitness of ultramarine for painting on glass and porcelain. Solutions of potassa and soda have no decomposing action, even at a boiling temperature. By a prolonged red heat ultramarine is rendered perfectly white, and then no longer evolves sulphide of hydrogen on the addition of an acid.

Tests.—Purchasers frequently judge of the comparative value of samples of ultramarine by mere inspection—a most fallacious method. The eye may indeed decide on the purity of the blue, but it can give very little notion of its depth. In other words, it is impossible to determine, by mere inspection, how far a sample has been let down with some colorless substance. It is better to take equal weights of the respective samples under examination, and to grind up each with ten to twenty times its weight of gypsum. When thus let down, a difference in the depth of color becomes perceptible.

Bernheim prepares a normal solution by mixing one ounce of concentrated sulphuric acid with twenty grains of water; equal weights—fifty to one hundred grains—if the various samples to be examined are next taken, and each placed in a separate glass. The normal liquor is now added from a graduated burette until the blue color is converted into a reddish one, and no blue particles are perceptible. The quantity of sulphuric acid consumed in each case shows the relative value of the sample. If cobalt is present, the blue color of the sample cannot be completely destroyed by the acid.

Uses.—Ultramarine is employed as a pigment by artists and decorators. Under certain circumstances, however, it gradually loses its color if ground with oil. It is also used in printing cotton and woollen goods, being fixed to the fibre either by solutions of albumen and casein, or by shell-lac varnishes. It is abundantly employed as a *powder-blue*, in getting up white cotton and linen goods. For this purpose it is ground up with soda-ash, chalk, gypsum, or any other cheap white matter, and sold sometimes under its own name, but more frequently as superfine Saxon smalts. This fraud is much in vogue in a sea-port town on the Eastern coast of England notorious for its manufacture of inferior and spurious colors. The detection is not difficult, since hydrochloric acid at once destroys the color of ultramarine, whilst it is without action upon genuine smalts.

VARNISH.—*Vernis*, French; *Firniss*, German.—In the commonest acceptation of the term, a varnish consists of a resin of some description dissolved in a fluid more or less volatile, which, on evaporation, leaves the resin in the form of a lustrous film. It is generally applied by means of a brush in successive coats, and is laid on in the direction of the fibres of the wood. The most desirable feature of a good varnish is durability, dependent upon the quality of the resin and its solvent.

The principal substances employed in making varnishes are the following:—

SOLVENTS.

Oil of nuts—alcohol.
Oil of linseed—ether.
Oil of turpentine—wood-spirit, pyroxilic alcohol, or hydrated oxide of methyle.
Oil of rosemary—methylated spirit.

SOLIDS.

Amber,
Anime,
Benzoin,
Colophony,
Copal,
Damara,
Sandarac.
Elemi,
Lac,
Mastic,

COLORS.

Aloes,
Annotto,
Cochineal,
Dragon's blood,
Gamboge,
Indigo,
Red saunders,
Saffron,
Turmeric.

The spirituous varnishes dry most rapidly; this advantage is, however, partly counterbalanced by their aptitude to crack and to peel off. This defect is partially remedied in the turpentine varnishes which dry more slowly. But in those called *oil-varnishes*, this defect is alone entirely obviated: in these a small quantity of a drying oil is added to the solution of the resin in rectified spirit of turpentine; and although they take a longer time to dry, they are all the more durable.

Before treating of the various varnishes, a description will be given of the chief resins before mentioned, as being employed in the manufacture:—

Amber is most distinguished for durability. It is usually of some shade of yellow, transparent, hard, and moderately tough. Heated in air it fuses at about 549°; it burns with a clear flame, emitting a pleasant odor. When pounded, absolute alcohol extracts succinic acid and resin; the latter to the extent of about one-eighth of the weight of the amber. In fact, amber is a mixture of several resins. It resists the action of solvents so greatly, that it requires to be fused and kept in a state of fusion—for oxidation—at a somewhat high temperature before it is fitted for making amber-varnish. The costliness of amber, as well as the length of time it takes to dry, are the chief objections to it.

Anime is imported from the East Indies. The large, transparent, pale-yellow pieces, with vitreous fracture, are best suited for varnish. Inferior qualities are employed for manufacturing gold-size or japan-black. Although superior to amber in its capacity for drying, and equal in hardness, varnish made from anime deepens in color on exposure to air, and is very liable to crack. It is, however, much used for mixing with copal varnish.

Benzoin is a gum-resin but little used in varnishes on account of its costliness. The finer sorts are brittle, pulverulent, with conchoidal fracture; they fuse at a gentle heat.

Colophony is synonymous with arcanson and rosin. When the resinous juice of *Pinus sylvestris* and other varieties is distilled, colophony remains in the retort. Its dark color is due to the action of the fire. Dissolved in linseed oil or in turpentine by the aid of heat, colophony forms a brilliant, hard, but brittle varnish.

Copal is a gum-resin of immense importance to the varnish-maker. It consists of several minor resins of different degrees of solubility. In durability it is only second to amber; when made into varnish, the better sorts become lighter in color by exposure to air.

Copal is generally imported in large lumps about the size of potatoes. The clearest and palest are selected for what is called *body-gum;* the second best forms *carriage-gum;* whilst the residue, freed from the many impurities with which it is associated, constitutes *worst quality*, fitted only for japan-black or gold-size.

Copal is tasteless and inodorous; transparent and of conchoidal fracture. Heat softens it without rendering it viscid. In alcohol it is but little soluble; but it is said to become more so by reducing it to a fine powder, and exposing it to atmospheric influences for twelve months. Boiling alcohol or spirit of turpentine, when poured upon *fused* copal, accomplishes its complete solution, provided the solvent be not added in too large proportions at a time. The addition of camphor also promotes the solubility of copal; so likewise does oil of rosemary.

Dammara is a tasteless, inodorous, whitish resin, easily soluble in oils. It is not so hard as mastic, with which it forms a good admixture.

Elemi is a resin of a yellow color, semi-transparent, and of faint fragrance. Of the two resins which it contains, one is crystallizable and soluble in cold alcohol.

Lac constitutes the basis of spirit-varnish. The resin is soluble in strong alcohol aided by heat. Its solution in ammonia may be used as a varnish, when the articles coated with it are not exposed more than an hour or two at a time to water.

Mastic is a soft resin of considerable lustre. The two sorts in commerce are, *in tears* and the *common mastic;* the former is the purer of the two. It consists of two resins—one of which is soluble in dilute alcohol. With oil of turpentine it forms a very pale varnish of great lustre, which flows readily and works easily. Moreover, it can be readily removed by friction with the hand; hence its use for delicate work of every description.

Sandarac is a pale odorous resin, less hard than lac with which it is often associated as a spirit-varnish. It consists of three resins differing as to solubility in alcohol, ether, and turpentine. It forms a good pale varnish for light-colored woods; when required to be polished, Venice turpentine is added to give it body.

Of the solvents of these various resins little need be said. In the manufacture of varnishes great care, as well as cleanliness, are required. The resins should be washed in hot water, to free them from particles of dust and dirt; they should be dried and assorted according to their color, reserving the lightest shades for the best kinds of varnish.

The *linseed-oil* should be as pale-colored, and as well clarified as possible. New oil always contains mucilage, and more or less of foreign matters; as these prevent the regular absorption of oxygen, the oil requires preliminary treatment. The common plan is to boil it with litharge; but such *oil varnish* is inferior to that prepared with sulphate of lead.

The best method is to rub up linseed-oil with dry sulphate of lead in sufficient quantity to form a milky mixture. After a week's exposure to the light and frequent shaking, the mucos deposits with the sulphate of lead, and leaves the oil perfectly clear. The precipitated slime forms a compact membrane over the lead, hardening to such an extent that the clarified oil may be readily poured off.

Turpentine is of very extensive use. The older it is, the more ozonized, the better it is. Turpentine varnishes dry much more readily than oil varnishes, are of a lighter color, more flexible and cheap. They are, however, neither so tough nor so durable.

Alcohol is employed as the solvent of sandarac and of lac. The stronger, *cæteris paribus*, the better.

Naphtha and *methylated spirit of wine* are used for the cheaper varnishes. Their smell is disagreeable. The former is, however, a better solvent of resins than alcohol.

Spirit Varnishes.—Mix—

Alcohol	500 parts.
Ether	60 “

Heat in a flask, and suspend therein from a bag, one hundred and twenty parts of finely-divided well oxidized copal. Continue the heat until complete solution takes place. Such a varnish combines brilliancy and transparency with considerable hardness and solidity. As color is easily generated over the fire, the materials are best digested in a water bath. Such a varnish is, however, only suitable for fancy articles, and is, after all, not equal to a mixture of resins.

A VARNISH FOR PAPER, MAPS, ET CETERA.

	Parts
Spirit of wine,	32
Mastic,	6
Sandarac,	3
Venice turpentine,	3
Pounded glass,	4

Mix the pounded mastic, sandarac, and glass thoroughly together, and place them in a tinned copper digester. Add the alcohol, stir well and frequently with a wooden spatula, and heat for several hours in a water bath. When the solution is complete, add the turpentine, stir frequently, continuing the heat for an hour, and strain when cold through a cloth.

This method is applicable to all spirit varnishes.

A WHITE SPIRIT VARNISH FOR VIOLINS.

Spirit of wine,	One gallon.
Mastic,	Two pounds.
Turpentine varnish,	One pint.

A VARNISH FOR WHITE WOODS.

Bleached shellac,	Three pounds.
Spirit of wine,	Two and a half gallons.

The shellac should be first dissolved in a gallon of the spirit, and the rest added after straining.

ANOTHER VARNISH FOR MUSICAL INSTRUMENTS.

	Parts.
Spirit of wine,	32
Sandarac,	4
Pounded glass,	4
Seedlac,	2
Mastic in tears,	2
Venice turpentine,	2
Elemi,	1

These varnishes may be readily colored—*red*, by dragon's blood; *yellow*, by gamboge. If a colored varnish is required, clearly no account need be taken of the color of the resins. Lac varnish may be bleached by Mr. Lemming's process:—Dissolve five ounces of shellac in a quart of spirit of wine; boil for a few minutes with ten ounces of well-burnt and recently-heated animal charcoal, when a small quantity of the solution should be drawn off and filtered: if not colorless, a little more charcoal should be added. When all tinge is removed, press the liquor through silk, as linen absorbs more varnish; and afterwards filter it through fine blotting-paper. Dr. Hare proceeds as follows:—Dissolve in an iron kettle about one part of pearlash in about eight parts of water, add one part of shell or seed lac, and heat the whole to ebullition. When the lac is dissolved, cool the solution, and impregnate it with chlorine gas till the lac is all precipitated. The precipitate is white, but the color deepens by washing and consolidation. Dissolved in alcohol, lac bleached by this process yields a varnish which is as free from color as any copal varnish.

One word in conclusion with reference to all spirit varnishes. A damp atmosphere is sufficient to occasion a milky deposit of resin, owing to the diluted spirit depositing a portion: in such case the varnish is said to be *chilled.*

Essence Varnishes.—They do not differ essentially in their manufacture from spirit varnishes. The polish produced by them is more durable, although they take a longer time to dry.

Table Varnish may be made as follows:—

Damma resin,	1 pound
Spirits of turpentine,	2 pounds
Camphor,	200 grains

Digest the mixture for twenty-four hours. The decanted portion is fit for immediate use.

COMMON TABLE VARNISH.

Oil of turpentine,	1 pound
Bees' wax,	2 ounces
Colophony,	1 drachm

COPAL VARNISH FOR INSIDE WORK.

Pounded and oxidized copal,	24 parts
Spirit of turpentine,	40 “
Camphor,	1 “

FLEXIBLE COPAL VARNISH.

Copal in powder,	16 parts
Camphor,	2 “
Oil of lavender,	90 “

Dissolve the camphor in the oil, heat the latter, and stir in the copal in successive portions until complete solution takes place. Thin with sufficient turpentine to make it of proper consistence.

Oil Varnishes.—These, the most durable and lustrous of varnishes, are composed of a mixture of resin, oil, and spirit of turpentine. The oils most frequently employed are linseed and walnut; the resins chiefly copal and amber, but also the others already recorded.

The drying power of the oil having been increased by litharge, red-lead, or by sulphate of lead, and a judicious selection of copal having been made, it is necessary, according to Booth, to bear in mind the following precautions before proceeding to the manufacture of varnish:—1. That oil varnish is not a solution, but an intimate mixture of resin in boiled oil and spirit of turpentine. 2. That the resin must be completely fused previous to the addition of the boiled or prepared oil. 3. That the oil must be heated from 250° to 300°. 4. That the spirit of turpentine must be added gradually and in a thin stream, while the mixture of oil and resin is still hot. 5. That the varnish be made in dry weather, otherwise moisture is absorbed, and its transparency and drying quality impaired.

The heating vessel must be of copper, with a rivetted and not a soldered bottom. To promote the admixture of the copal with the *hot* oil, the copal—carefully selected and of nearly uniform fusibility—is *separately* heated with continuous stirring over a charcoal fire. Good management is required to prevent the copal from burning or becoming even high colored. When completely fused, the heated oil should be gradually poured in with constant stirring. The *exact* amount of oil required must be determined by experiment. If a drop upon a plate, on cooling, assumes such a consistency as to be penetrated by the nail without cracking, the mixture is complete; but if it cracks, more oil must be added.

The spirit of turpentine *previously heated* is added in a thin stream to the former mixture, care being taken to keep up the heat of all the parts. With proper attention to these directions, the following prescriptions from Dumas, Tomlinson, Booth, and others, will be found of use:—

COPAL VARNISH FOR FINE PAINTINGS.

Gum copal, fused,	8 pounds
Linseed oil, heated to 250°,	2 gallons

Boil for about a quarter of an hour, until the mixture strings strongly, and then add spirit of turpentine, hot, three gallons. Although much loss of turpentine ensues, the varnish will be so much the more transparent, durable, and drying.

CABINET VARNISH.

Copal, fused,	14 pounds
Linseed oil, hot,	1 gallon
Turpentine, hot,	3 gallons

Properly boiled, such a varnish will dry in ten minutes.

BEST BODY COPAL VARNISH.

Copal, fused,	8 pounds
Linseed oil, hot,	2 gallons
Turpentine, hot,	3½ “

The mixture must be slowly boiled for five hours until quite stringy, and subsequently mixed with the heated turpentine. This varnish is well suited for all objects intended for polishing.

In preparing *artists' copal varnish* it is advisable to separate the particles of copal by means of pounded glass, to prevent the gum from adhering, so that a moderate fire will suffice. The older the turpentine the more drying the varnish. Take—

Finest picked copal,	3 pounds
Pounded glass,	2 “
Linseed oil,	3 quarts
Spirit of turpentine,	5 “

All the before-mentioned varnishes are recommended to be made with clarified, but not otherwise prepared oils. Consequently they take long to dry, and cannot be polished for months. Anime is often introduced to hasten the hardening of the varnish, in the proportion of one part to two of copal. But such varnish is less durable. A yet inferior copal varnish contains anime in the proportion of two parts to one of the former.

WAINSCOT VARNISH FOR HOUSE PAINTING AND JAPANNING.

Anime,	8 pounds
Clarified linseed oil,	3 gallons
Litharge,	½ pound
Acetate of lead,	½ pound
Sulphate of copper,	½ pound

All these materials must be carefully but thoroughly boiled together until the mixture becomes quite stringy, and then five and a half gallons of heated turpentine stirred in.

Such a varnish is, of course, every way inferior to one made with a carefully prepared drying oil, as above prepared by the aid of sulphate of lead. But it exsiccates very rapidly, and is well suited to the common purposes for which it is intended. It can be easily deepened in color by the addition of a little gold-size.

The varnish used in India for palanquins is made by melting a kind of sandarac, and mixing it with boiling and drying linseed oil. Mr. RHODE, in *Balfour's Cyclopædia*, knows of no better or more durable polish for teak and chittagong wood particularly, than may be prepared by melting three or four bits of sandarac, of the size of a walnut or small egg, and pouring upon it a bottle of boiling linseed oil previously rendered drying by boiling litharge or other dryer, and after boiling them together gently for an hour, adding while cooling a teaspoonful of venice turpentine. If too thick, it may be thinned with spirit of turpentine. It should be rubbed on the furniture, and after a little time—during which it may be exposed to the sun—rubbed off. The friction should be continued daily, and the polish should not be again applied for eight or ten days; after which it may be slightly applied every one or two months. Water does not injure this polish, and any stain or scratch may be rubbed over, which cannot be done with French polish. To give the appearance of gold to silver leaf used by the Condapilly Moochies, for ornamenting boxes, palanquins, *et cetera*, a little aloes is dissolved in the varnish, which is laid over it. A very good varnish is prepared by Moochies with shell-lac and wood oil, heated in small quantities.

French polish is employed upon flat surfaces, and consists simply of a solution of resin in spirit of wine. The simplest sort of French polish may be made by dissolving one and a half parts of shell-lac in eight parts of spirit of wine. Such a polish is very durable, but many other gum-resins are employed. A good dark-colored polish is prepared from one pound of shell-lac, half a pound of gum-benzoin, and one gallon of spirit of wine. Others recommend twelve ounces of shell-lac, three ounces of copal, six ounces of gum-arabic, to one gallon of spirit.

The *lacker* used for wood work or brass is also a varnish. For brass the proportions are half a pound of pale shell-lac to one gallon of spirit of wine. It is better prepared without the aid of heat, by simple and repeated agitation. It should then be left to clear itself, and separated from the thicker portions and from all impurities by decantation. As it darkens on exposure to light, the latter should be excluded. A pale yellow lacker may be made by mixing one ounce of gamboge, and two ounces of Cape aloes, with one pound of shell-lac. For a bright yellow half a pound of turmeric and two ounces of gamboge are required; for a red lacker, half a pound of dragon's blood and one pound of annotto. It need scarcely be said that the color will also be modified by that of the lac employed.

WATER.—*Eau*, French; *Wasser*, German; *Aqua*, Latin.—The poet SOUTHEY thus appositely writes of this all-important fluid:—

> Most blessed water! neither tongue can tell
> The blessedness thereof; no heart can think,
> Save only those to whom it has been given
> To taste of that divinest gift of heaven.

In the very first record of that fiat of the Creator, which called forth by omnipotent volition the innumerable planetary bodies distributed in infinite space, the primary matter especially mentioned is water: *And the Spirit of God moved upon the face of the waters.* Whether the circumstances of the creation, as related in Genesis, differ from the order observed in giving form to, and producing diversity of, objects upon the earth by the *great First Cause*, is a question which does not affect one way or another, the subject of the present article; although the study of the disposition of the principal objects within the limited range of man's sphere of inquiry, geographically and geologically considered, demonstrates most conclusively, that water has fulfilled functions in the formation of mineralized and other strata in the solid crust of the earth, of undeniable importance. It is not previous to the generation of vegetal and animal life, however, that the importance of water, as an abundant and primary constituent of the globe, can be properly estimated; for it is only in the fulfilment of the higher designs of Providence, such, for instance, as the production and sustenance of vegetal and animal life and organization, that any approach to an adequate notion of the great ends which water serves, can be formed. Without water no organized structure, whether of vegetal or animal, could, in the human estimation of things, preserve its functions and reproduce itself in obedience to the great generic law of Nature. Independently of its essential importance in this respect, water serves another purpose only secondary to it—namely, that of distributing a medium temperature over the whole surface of the earth, conformably to certain physical laws which will be subsequently alluded to, thereby insuring a genial warmth which is absolutely necessary for the development of plants and animals. It may be assumed, that for some such or other similar all-wise dispensations, the extent and quantity of water on the globe greatly surpasses that of the land. It is well known that water is capable of combining with caloric to a great degree; and, owing to the superficies of the globe being to the extent of two-thirds, water, it is evident the chief portion of the heat derived from the sun is stored in this liquid, for the purpose merely of being eliminated gradually to compensate the earth for that which, owing to its superior radiating power, it gives off so freely as to chill it to a degree prejudicial to organized life, unless supplied by winds or air-currents, passing over the surface of large tracts of waters. This capacity of storing caloric possessed by water is subservient in other respects, not only for equalizing the heat of the habitable portions of the globe, but for the distribution of the liquid itself over the arid parts of the earth. For instance, the warm rays of the sun would be unendurable in the torrid zone, were it not that in these regions large quantities of water are evaporated, and that every unit of it thus converted into vapor renders latent or insensible above one thousand units of heat, thus beautifully neutralizing the violent effect of the sun's intense rays. Again, the aeriform moisture ascends obedient to its expansive force, and diverges laterally to colder regions, where the water having parted with a great portion of its acquired temperature, condenses into clouds, and finally falls as rain, hail, or snow, to refresh and nourish life in its multifarious varieties;

whilst a current of air from colder regions loaded with water rushes to the locality whence it was driven, to compensate the loss of moisture, and maintain the equilibrium of temperature. Thus is a beautiful provision for the preservation of organic life and the maintenance of a genial warmth sustained, a provision which, from its regularity and precision, is called a physical law, though in reality a divine and beneficent dispensation.

Water is therefore of primary importance as well in the physiology as in the economy of life, and quite as indispensable as the air breathed from the dawn to the close of man's existence; without them all other provisions of nature would, under existing circumstances, be inadequate to sustain vitality.

History.—In considering water scientifically, it offers a wide and an interesting field of inquiry to the aspiring student. For a long time many earnest minds were misled regarding its nature, nor was it till almost within the span of the present age—namely, in 1781—that its true composition was revealed. Formerly, philosophers, universally following the footsteps of the ancients, regarded it as one of their elements, though, in later times, some among them were found who considered it transmutable into an earth by repeated distillations, in consequence, as **Lavoisier** subsequently proved, of the glass vessels in which the operations were performed, undergoing slight disintegration on the surface, and giving rise to a crust of silicious and other matters contained in the glass. Its real nature lay hidden and subject to conflicting hypotheses till, by the superior powers of deduction, aided by a deep and patient penetration into the secrets of phenomena, according to the principles of chemistry as then understood, **Cavendish**, by most conclusive and beautiful researches, as well synthetically as analytically, revealed its true nature as a compound body. Like all other inventions and discoveries of great importance, there were others ready to claim the honor, such as **Watt** and **Lavoisier**; but evidently the principles which they enunciated appear to have originated with **Cavendish**, and had been communicated through **Priestley** and others to the forementioned philosophers, previous to the publication of the account of **Cavendish's** researches on the subject. The light thus shed upon the knowledge of chemical phenomena, might appropriately be placed in juxtaposition with the brilliant lustre emanating from the discovery of oxygen by a **Priestley**, or from that of the atomic theory by a **Higgins** and a **Dalton**. The phenomena attending the combustion or explosion of hydrogen gas in common air, and the endeavors of **Warltire** to deduce from the experiment whether or not caloric was ponderable, seem to be the primary facts that led subsequently to the discovery of the composition of water. **Priestley**, **Warltire**, and doubtless others, too, repeated the experiment frequently; and although water was a product in every instance, yet no one before **Cavendish** seems to have given the necessary attention to the question of how this water was formed. After numerous trials regarding the proportions of air and hydrogen that were required to produce this important liquid, **Cavendish** found these to be two volumes of hydrogen and five of air. Subsequently the research in this direction recommended itself to other philosophers, among whom **Gay-Lussac** fixed the respective quantities of the component gases necessary to produce water at one volume of oxygen and two of hydrogen.

Preparation.—When two volumes of hydrogen and one of oxygen gas are mixed in a confined vessel and ignited by means of the electric spark, a slight flash of light and loud explosion follow their combination, and water remains in the vessel to the extent of the weight of the combined gases. In like manner, when hydrogen issuing from a small jet is ignited, and a deep cylindrical glass is inverted on the flame, water is produced; and, owing to it being condensed on the cold surface of the glass, appears first as a slight coating of dew, and subsequently in the form of small drops which trickle down the walls of the vessel. Many other means are now known, whereby pure water from its elements is produced, such, for instance, as transmitting pure hydrogen gas over several metallic oxides inclosed in tubes, and heated to redness. The most conclusive experiment for demonstrating the composition of water is that performed by the aid of the galvanic battery. In this experiment, the constituent gases are evolved at the respective poles of the battery in the ratio of two volumes of hydrogen and one of oxygen; and by mixing these gases in a eudiometer or other tube, and transmitting the electric spark through them, water is again reproduced. It would be tedious to specify the numerous ways in which water can be formed from the combustion of hydrogen. It may be instanced, however, that finely-divided platinum—platinum black—possesses the power of causing the combination of the gaseous constituents of water in a remarkable manner. The principle of **Dobereiner's** instantaneous light is founded on this same property.

The arrangement by which the decomposition of water may be illustrated, consists simply of a glass globe with stopper openings at the sides and at the top, filled with water. Small platinum wires pass through the corks at the sides, and up through the apertures at the top, terminating in flat plates of the same metal. Two graduated tubes filled with water are inverted over these plates, and the zinc and copper poles of a voltaic battery connected with the protruding wires at the side, thus converting the two tubes into ordinary decomposing cells. On setting the battery in action, the water in the tubes will undergo decomposition in part, oxygen being formed on the side of the copper or positive pole, and hydrogen on that of the zincoid or negative pole; both gases, as they accumulate, ascend to the closed ends of the tubes, forcing out the water. By reading the index on the tubes, it will be found that the quantity of hydrogen in the tube inverted on the zincoid pole will be strictly double the volume of the oxygen in the other; in other words, the elements are evolved in the exact ratio of their existence in water, as may be proved experimentally by exploding the mixture of both gases in a cylinder over mercury.

Properties of Water.—Water, like gases and elastic bodies generally, possesses very varied properties both of a physical and a chemical nature. The knowledge of the former constitutes the chief division of two correlative branches of the physical sciences, namely, hydrostatics and hydrodynamics; the former relating to the equilibrium, or the statical momentum of this fluid, and the latter, to the order of its motion under unequal forces. As the knowledge of these is more particularly connected with the science of mechanics or engineering, they need not be specially dwelt upon here.

Pure water has neither taste nor smell; it is colorless in small bulk, but of a greenish hue when seen in large masses. Water is solid at temperatures below 32°, liquid between 32° and 212°, and gaseous at a higher heat. By a careful method of reducing the temperature of water, and guarding against any agitation of the liquid or contact with any angular body, the point of solidification descends as low as 8°, or even 5°; that is, 24° and 27° below the point at which it freezes when it is agitated. In like manner, if the ordinary pressure under which it boils at 212°, namely, thirty inches of mercury, be reduced, the phenomenon of ebullition succeeds at considerably lower degrees of heat. Thus it is that on the summit of high mountains, where, in consequence of the elevation, the normal pressure of the atmosphere is lessened, water is observed to boil at a lower thermometric degree than at the base. In the act of solidification water resolves itself into numerous forms, one of which is a rhomboid, closely resembling Iceland spar. Under ordinary circumstances, when its particles are in equilibrium, water is elastic and compressible. This property had long since been proved by **OERSTED**, and modernly has been established by **PERKINS**. The results are, however, variously stated: thus, **PERKINS** found that by a pressure of three hundred and twenty-six atmospheres, the compression amounted to ·035 of the bulk, or a value of one hundred and eight millionths for every atmosphere; whereas, when the strain was raised to two thousand atmospheres, the reduction was less than one-half of the above for each atmosphere, namely, forty-one millionths. **OERSTED** found the average reduction per degree to be forty-five millionths of its bulk; he likewise observed that the contraction increases in direct proportion to the power exercised in compressing it, up to seventy atmospheres. Water is likewise subject to compression and extension when under the influence of another power, namely, that of heat, but with greater irregularity than is observed when acted upon by mechanical force. Generally speaking, the abstraction of heat from bodies serves to bring their particles closer together, and therefore contract them, and *vice versâ;* but the axiom is true with regard to water only within certain limits. For instance, when ice is melted by causing it to combine with caloric, instead of expanding with each increment, its bulk suffers a diminution till the temperature of the mass rises to 39·2°, at which degree it has been found to possess its greatest density; on continuing the addition of heat, however, it begins to expand till the boiling point is attained, the acquired bulk in this range being, according to the researches of **HALSTROM**, one part in twenty-four. The experiment can be easily illustrated by a glass vessel fitted with a narrow tube; the contraction and expansion of the water in the flask being indicated by its descent or rise in the capillary tube inserted into its mouth. The peculiarity attending a change of temperature in water, between the limits of 32° and 48° may be shown to vary from the expected effects resulting under ordinary circumstances from the addition or abstraction of caloric; thus, the expansion which is observed to take place in the liquid from its point of greatest density, 39·2°, when heated through a range corresponding to that between this and the freezing point, equals exactly that which a reduction of temperature from 39·2° towards the freezing effects, so that the volume at 48° and 32° is exactly the same.

The following table of the contraction and expansion of water between the three points, 32°, 39·2°, and 212°, gives the results arrived at by **KOPP**:—

Temperature	Volume.
32·0	1·000000
33·8	·999947
36·5	·999908
37·4	·999885
39·2	·999877
41·0	·999883
42·8	·999903
44·6	·999938
46·4	·999986
48·2	1·000048
50·0	1·000124
51·8	1·000213
53·6	1·000314
55·4	1·000429
57·2	1·000556
59·0	1·000695
60·8	1·000846
62·6	1·001010
64·4	1·001184
66·2	1·001370
68·0	1·001567
69·8	1·001776
71·6	1·001995
73·4	1·002225
75·2	1·002465
77·0	1·002715
86·0	1·004064
95·0	1·005697
104·0	1·007531
113·0	1·009541
122·0	1·011766
131·0	1·014100
140·0	1·016590
149·0	1·019302
158·0	1·022246
167 0	1·025440
176·0	1·028581
185·0	1·031894
194·0	1·035397
203·0	1·039094
212·0	1·042986

This peculiar behavior of water is not only interesting as a curious deviation of a natural law, but because it serves purposes of the highest importance in the economy of Nature. The hardest rocks are split asunder by the freezing and expansion of the water which penetrates their fissures, soils are disintegrated, and their hidden elements of nutrition presented in a state fit for absorption by the roots of plants.

When the great body of water of the globe is cooled on the surface, the exposed portion, owing to its density being slightly increased, sinks, causing the warmer substratum to rise, to manifest the same behavior when its temperature is lowered in like manner. Did this circulation continue till the entire mass acquired a freezing temperature, it is evident that the whole body of water would enter nearly at once into the solid state of ice, to the destruction of all living creatures inhabiting it, to the destruction of oceanic commerce, and of the communion of peoples separated by large tracts of oceans and seas. Further, were such the order of the laws governing Nature, not only would the living inhabitants of waters inevitably perish, but those on the land would also be destroyed, in consequence of the insupportable cold that would be produced in the atmosphere, owing to another property which water, whether in the liquid or solid state possesses, of combining with heat, and rendering it latent or insensible. The warmest seasons would be of little avail to counteract such dire effects, and the genial climate of temperate zones would be changed to a far worse condition than the frigid regions of the North pole! Providentially, however, the progress of the cooling and consequent circulation induced in water by cold is arrested when the whole mass reaches a temperature of about 40°, that is, 8° above the freezing point; for at this limit, instead of contracting and sinking it becomes specifically lighter by expansion, and therefore remains floating on the subjacent mass. By a continued reduction of its temperature the surface will ultimately freeze, and the crust of ice may go on thickening; but it is inconceivable what cold could thus convert the entire mass into the solid form in this way. Hence, even in the perpetually frozen regions of the North, the water beneath the ice retains a heat of 40°—a temperature much higher than is experienced in this climate often during Winter—and suited not only to marine animals, but calculated, under the least favorable change, to aid in bringing about the normal state of things best suited to the wants of the great family of God's creatures.

From the preceding remarks, the cause of ice—solidified or crystallized water—floating in water will be readily understood. It has been shown that at the point of solidification the liquid has the same, if not a lesser density than at 40°; but, in passing to the solid state, the gravity is much further reduced, as well by the arrangement which its particles assume, as by the expulsion of the gases dissolved in the water, and which, before they can escape, are enveloped and compressed within the solid crystal. From both, and perhaps other conjoint causes, the density of ice at a temperature of 32° is less than that of water at 212°, and hence the former floats in the latter. At the normal degree at which chemists are accustomed to compare the densities of bodies, namely 60°, and a barometric pressure of the atmosphere of thirty inches, pure water is taken as the standard of comparison, and is expressed by unity, or 1000—compared to this ice has a density of 0·916.

Another circumstance which prevents the freezing of the waters of the oceans is the quantity of saline matters which they hold. **Despretz** found that all such saline solutions have a point of maximum density, which is so far below 39·2° as the solution is richer in salt, and this point of maximum density is even below the freezing point of these solutions when agitated, although in a quiescent state they may be cooled below it without assuming the solid form. The following are the results of his researches on this subject, with solutions of 3·759 parts of the undermentioned compounds in one hundred of water:—

	Maximum density,		Freezing point
Potassa, ...	21·80	....	28·22
Carbonate of potassa, ...	24·89	....	26·22
Sulphate of potassa, ...	27·90	....	28·24
Carbonate of soda..........	19 38	....	26·87
Sulphate of soda, ...	24·21	....	27·84
Chloride of sodium, ...	24·45	....	27·02
Chloride of calcium, ...	26·95	....	26·95
Dry sulphate of copper,....	30·89	....	29·63

In considering the effects of heat upon water, a further insight into the beautiful provisions of Nature may be obtained. It has been stated in the preceding that water is the medium by which the great heat of warm climates is assuaged. Here it may be well to explain a little more fully how this is effected. Water, of all known substances, has the greatest capacity for heat—that is, its power of combining with this imponderable, and exhibiting in a less degree its effects in point of warmth than any other body. This property is possessed by it in its several forms of solid, liquid, and vapor or steam. If a given weight of ice, indicating a temperature of 32° be added to an equal bulk of water at 135°, and the mixture be left at rest till the former is melted, the temperature of the mixture on being essayed will not be the mean of the two degrees of heat—83·5°—as might be anticipated, but it will be found at the same standard as that of the ice itself before its introduction to the hot water. Hence it is evident that ice, or water, in passing from the solid to the liquid state, renders latent as much sensible heat as would bring it to about half the temperature of boiling water, were it in the liquid state at 32°; or within 52° of boiling water, were it at the normal temperature of 60°. **Regnault's** results on this subject are 142·6°, as the amount of heat rendered latent by water in passing from the solid to the liquid state. All this latent heat is evolved from the water in passing to the solid state of ice; and thus does it beautifully serve to soften the rigor of the cold necessarily felt by those in polar climes. In its liquid state, between 32° and 212°, water manifests the same power of uniting with heat, and showing less of its effects sensibly than any other body. For instance, when a pound weight of water at 100° is mixed with the same weight of itself, of olive oil, and of mercury respectively, at 40°, it will be found that the temperatures of the resulting mixtures will not be the same; the mixture of the waters will show the exact mean of their respective heats before mixing, that is 70°; but that of the water and oil will be 80°, and of the mercury and water will be 98°. Hence it will be seen that the same quantity of heat which in the last instance produced an effect of 2° on water, raised the same weight of mercury 58°; and that of 20° in the case of the mixture, water and oil, equalled an effect of 40° on the oil alone. The consequences of this capacity for heat are most important in retaining the temperature of bodies at a medium point, and its value to the human frame in hot climates is almost incalculable; for when taken into the system, or evaporated from the parched and inflamed skin of the inhabitants of dry and arid countries, it reduces the heat of the system more than the same weight of any given substance.

When water is evaporated, the caloric which is thus carried off, and with as little sensible effect as that absorbed by the ice during its transition from solid to a liquid, is very great. Water may be boiled in a vessel, and although heat is transmitted to it, during the period of its evaporation, in a continuous stream, yet the heat of the liquid does not rise beyond 212°, nor does the vapor exceed the same; necessarily, therefore, the whole of the caloric absorbed must be rendered latent in the vapor formed. This may be proved to be the case by transmitting a given weight of the vapor of water—steam—at 212° into a measured bulk or weight of water at any degree, such for instance as 32° or 60°, and noting the effect. In this way it has been found by **Dulong** to contain as much as 977·4° of latent heat, which, added to its sensible caloric, 180°—the difference between 32° and 212°—gives a total of 1157 degrees, or units of heat, possessed by every unit of water in the form of steam at 212°. Without dwelling upon the importance in an industrial point of view of this property which water possesses of combining with heat on assuming the gaseous form, and parting with the same wherever this vapor is transmitted to and condensed, or on the power which an accumulation of the vapor at its normal temperature, or at a higher heat, exercises in the thousands of varied forms in which steam is employed in connection with mechanism and industrial works of arts and manufactures—it will be well to cite this property in further proof of the profound beauty of the conception which, as stated in the introduction, has ordained this to be the medium of modifying the rigor of seasons and the influence of the geographical position of lands. Thus the water which is evaporated within the tropics, and which takes up with it an amount of heat corresponding to 1100°, conveys this heat towards the frigid zones, where, on being condensed either into rain, hail, or snow, it is given out to the air and surrounding objects, and thereby greatly contributes to the mildness and habitableness of those parts. Water evaporates not only at 212°, but at all intermediate temperatures between this and its freezing point; and even when in the state of ice, it has been ascertained that it gives off a very rarefied steam. In all these cases the quantity of heat which it renders latent increases with the degree of rarefaction, so that the same weight of steam, or watery vapor, produced at 60°, contains much more insensible heat than when generated at the boiling point of water.

The chemical relations of water are likewise of the utmost importance. In solvent power, that is, its power of overcoming the cohesion of particles of matter, it has no equal; and this force is exercised in reference to gases and liquids, as well as solid bodies; only that in the case of gases, instead of overcoming the cohesive force of the substance, the reverse is the effect, for it is the repulsive force or their expansion that is, so to speak, neutralized. To this phenomenon of destroying the repulsive force of the particles of gases, and the cohesive in solids or liquids, the term *solution* is applied; and, as is well known, it can in some cases be effected by heat, although in these the change is properly designated *fusion.* Water does not manifest the same behavior, however, with all solids, liquids, and gases, so that it appears the particles of the body capable of being affected in this way, must have a peculiar state of molecular aggregation which holds them together with a force inferior to that which water exerts upon them. There are therefore a numerous class of substances that are not affected at all under ordinary circumstances, and others to a very unequal degree, by water in this respect. For instance, a piece of rock crystal, calcareous spar, or glass, will remain in water a length of time without undergoing any change; but a crystal of sugar-candy, alum, or carbonate of soda, will be found to disintegrate readily, and disappear in the liquid. The former are said to be *insoluble*, and the latter *soluble* substances, in reference to water. Of those which are soluble in water, the quantity of them which the liquid is capable of combining with, till the equilibrium of the cohesion of the substance dissolved is attained—in other words, the point of saturation of the liquid with such a compound, is very variable, though almost in all cases more or less increased by heat. This may be readily proved by adding to equal weights of water, sugar, salt, or chloride of sodium and gypsum, exposing as great an extent of these as possible to the water by stirring the mixture, and then permitting to rest a while. If the solutions, say one pound of each, be evaporated, and the dry residue weighed, it will be found that the saccharine matter will weigh about twelve ounces, the saline residue about five and a quarter ounces, and the calcareous not more than fourteen or fifteen grains. Again, difference of temperature affects the solvent power of water, increasing it—except in few instances, such as when common salt and gypsum are the subjects, and which are nearly equally soluble in cold and hot water—with each additional degree of heat communicated to the liquid up to 212°; thus nitrate of potassa is dissolved in water at 57° to the extent of one-fourth, at 92° to that of one half, at 131° to an equal weight, and at 212° to the extent of twice the weight of the water employed. When the solutions made at the higher temperatures, however, are allowed to cool, the particles of the solids, over and above what is taken up at the normal degree, regain their cohesive force, and separate in the form of crystalline bodies. These reactions are of particular importance in a chemical point of view, as they offer a simple and ready means of separation and purification of many substances in various branches of manufacturing industry, the principles of which are governed by chemical laws. Another phenomenon connected with the solution of solids in water is, that in several instances a reduction of temperature takes place; while in other cases heat is evolved. Gay-Lussac has explained this anomaly. He found that when simple solution was effected of a salt, whether in a hydrated or anhydrous state, cold, or a reduction of the temperature of the liquid, resulted; but when chemical combination took place between the substance and the solvent, as, for instance, in the production of a definite hydrate, a rise of temperature is experienced. In the former case the salt, in passing from the solid to the liquid form, renders a quantity of heat greater or less according to its capacity for this imponderable, latent, and which is abstracted from the sensible temperature of the water; whilst in the latter the chemical force exerted in the act of combination develops an amount of caloric which is greater than that of the latent heat of the body, and hence the rise of temperature. The simple experiment of dissolving nitrate of potassa or chloride of ammonium in water will, with the aid of an ordinary thermometer, illustrate the truth laid down to the reader as regards the cold produced; and of hydrate or caustic potassa or sulphuric acid in reference to the heat developed. This reaction affords a ready means of distinguishing between chemical combinations with, and simple solution of a substance in water. In all these cases, however, with the exception of simple combination, water effects no change in the substance, so that by evaporation of the liquid, the solid matter may be again obtained, possessing the properties peculiar to it before solution. There are a few instances, however, in which water does not retain this neutral character; for with some of the salts of bismuth, antimony, and tin, its addition produces a decomposition, causing a liberation of the radical or acid of such, while itself in part undergoes decomposition. The reader will find these examples of decomposition illustrated under the respective metallic salts referred to.

To enter into the behavior of water with the alcohols, ethers, oils, resins, and other matters, would prolong the subject beyond prescribed limits; suffice it to say, that when alcohols partake of the nature of oils, they are not at all soluble in it; neither are ethers and oils, in the ordinary acceptation, dissolved by water; nor are the resins. Alcohol—that resulting from the fermentation of saccharine matters—is soluble in it in all proportions, although ether, the derivative of this body, and differing from it only by the elements of one equivalent of water, is almost insoluble in the liquid.

Behavior of Water with Gases.—Not only has water the property of liquefying a great number of solid bodies, but it exercises the same function with respect to many gases; a property that is of very great importance in the economy of nature in many instances.

To convey an adequate conception of the solvent power of water for gases, it may be stated that one hundred cubic feet, or six hundred and twenty-five gallons of water, at 60° and a barometric pressure of thirty inches, will dissolve of—

Hydrochloric acid gas,	50000·0	cubic feet.
Ammonia,	67000·0	"
Sulphurous acid,	5000·0	"
Sulphuride of hydrogen,	300·0	"
Chlorine,	200·0	"
Carbonic acid,	100·0	"
Carbonic oxide,	6·6	"
Binoxide of nitrogen,	5·0	"
Oxygen,	4·6	"
Nitrogen,	2·5	"

Water which has been much exposed to the air, such as rain water, absorbs two and a half parts of that compound; and what is so curious regarding it is, that the amount of oxygen in such, instead of being only twenty-one per cent., as in the atmosphere, was found to be so high as 34·8 per cent. by Gay-Lussac and Humboldt. Boussingault found that at an elevation of six to eight thousand feet, water absorbs not more than one third of the volume of air which it liquefies on the plain; which behavior has been cited as the cause of fishes not being found in the Alpine lakes situated at comparatively high altitudes; the small amount of oxygen in the soluble state in the water being thought insufficient to support the rêspiration of these cetaceous animals.

Many natural waters contain considerable quantities of nitrogen. Playfair estimated that the famous Buxton water, as it issues from the spring, is in combination with nearly three-fourths of its volume of nitrogen—as will be hereafter more discussed under its analysis. With so unnatural a phenomenon, the question, Whence does it come? at once intrudes itself. That it is assimilated from the air is impossible; and it is hardly conceivable that the water in passing through the calcareous strata of the district should meet with or take up such quantities of nitric acid and ammonia as would, by their mutual decomposition in some such manner as the following—

$$3\,NO_5 + 5\,NH_3 = 15\,HO + 8N,$$

give rise to the forementioned volume of gas.

Before entering upon the consideration of natural waters with respect to their hygienic qualities, *et cetera*, it may be stated that pure water at 62° and thirty inches barometric pressure, is taken for the standard to which the relative density of all other solids and liquids is compared; just as air is adopted as the standard for measuring the gravity of gases, both being assumed unity, or 1000. At the above degree of heat and pressure, one hundred cubic inches of it weigh 252·45 grains; consequently the imperial gallon weighs 70·000 grains, or ten pounds avoirdupois. It is eight hundred and fifteen times heavier than air, and one thousand three hundred and four times the weight of an equal bulk of its densest vapor, steam, generated at 212°. Its composition is represented as being one equivalent of hydrogen and one of oxygen—HO—and it has been found to contain—

	At. weight.	Centesimally.
1 Eq. hydrogen,	1	11·1
1 Eq. oxygen,	8	88·7
	9	100·0

Natural Water.—By this term is understood the ordinary liquid which serves the purposes of every-day life, whether its source be the rain, hail, or snow, which falls from the atmosphere; the drainings of the surface of the country, accumulated in lakes or rivers; well, or natural springs, through which the liquid permeating the porous strata of the earth at one place, finds an outlet or lower hydrostatic level at another; and sea or salt water. For the sake of clearness in the details which the Editor intends to lay before the reader on this subject, its consideration will be made in the following order, namely, rain, surface—including lakes and rivers—and spring or well waters, all embraced under the class Fresh Water; and Sea Water, or such waters as contain an abnormal quantity of foreign ingredients, and are therefore unfit for the more general uses to which this liquid is applied.

Fresh Waters.—*Rain and other Waters immediately derived from the Atmosphere.*—As already stated, there is a continual evaporation of water taking place from the surface of the land and sea, which is greater in warm latitudes, and lesser in the parallels approaching the frigid zones and the poles of the earth. This evaporation is dependent, in the first instance, on that curious property of gases, discovered by Dalton, by which a space filled with one kind of vapor or gas, offers as little obstruction to the diffusion of another vapor or gas, in the same space, as if it were already a vacuum; and in the second, upon the temperature. Some other conditions likewise affect the evaporation of water spontaneously, such as the quantity of moisture already contained in the atmosphere, the force and direction of the winds, *et cetera*, which need not be followed. Whilst the heat at which it was converted into an elastic vapor remains the same, watery vapor is quite as invisible as the air; but on sudden changes of temperature, occasioned by being brought into contact with a colder body of air, or any cooling surface, then the moisture is first condensed into very minute drops, forming clouds, and these drops continue to aggregate among themselves till their gravity becomes greater than the air, and they fall to the earth as refreshing rain. The theory of HUTTON, with respect to rain being produced by the mixing of opposite currents of air at different temperatures, though true to some extent, appears to be inadequate to produce the amount of rain which the numerous metereological observations so generally made during late years have registered; and it is therefore supposed that more rain is formed in close proximity to the earth, than in the higher regions of the air. The experiments of Professor J. PHILLIPS corroborate this in an extraordinary manner. He found that the fall of rain on the—

Top of York Minster,	242	feet high, was	15·910	inches.
Roof of Museum,	73	"	20·461	"
Surface of ground,	0	"	24·401	"

That all the rain of these latitudes could not be produced on Dr. HUTTON'S principle, may be readily conceived by considering the circumstances a little in detail. The tension of the vapor of water at 59° equals 0·5000 of an inch of mercury, and at 41° 0·2573; now, if equal bulks of air at these temperatures, saturated with water, commingle, the mean temperature of 50° will be attained, at which the tension of the aqueous vapor is 0·3608, the difference between which and 0·3786, the mean of the tensions above indicated, that is, 0·0178, represents the tension of the amount of water that would be condensed from the state of vapor. This quantity is very inconsiderable compared with that resulting from atmospheric changes which take place on or near the earth, as may be seen from the following example, quoted from GRAHAM. The mean temperature of January in this country is about 34°, but with a South-west wind the thermometer may be observed to rise gradually in the course of forty-eight hours to 54°; now, supposing such wind to be saturated with aqueous vapor, and that in traversing over the surface of the land it is cooled to 34°, the amount of moisture which it must deposit will be very considerable, as appears by the following—

Tension of vapor at	54°	equal to	0·429	inches mercury.
Do. do.	34°	"	0·214	"
Difference condensed as rain,			215	"

Invariably there is the greatest average fall of rain near the equator; it diminishes towards the poles, as the latitude is higher. The average annual fall of rain at—

New Granada, 12° 0′ N.	is 126 inches.
Calcutta, 19° 46′ N.	81 "
Rome,	39 "
England, average	31 "
London,	23 "
St. Petersburg,	16 "
Uleaborg,	13½ "

Snow and hail is a form of rain, in which the water is frozen before it reaches the earth; the former results from the formation of clouds at temperatures below 32°, wherein the minute drops are crystallized into an infinity of spiculæ, which arrange themselves into regular lines and figures, diverging from one another at angles of 60° and 120°. They are all referable, however, to the hexagonal and prism shape, though the details differ in almost every storm.

Hail is supposed to be formed in warm weather, when the sun is above the horizon, and under different circumstances to those calculated to produce snow. It is supposed to be produced in the ascending current of greatly rarefied air, by the cold consequent on such rarefaction, the force of the upward current being such as to carry with it the minute solid globule, till, by uniting with others, it attains a density that causes it to descend. Generally, this phenomenon of the production of hail is associated with a peculiar electrical state of the atmosphere, to which it must be principally attributed.

Rain, as it descends from the clouds, is contaminated with various gases and vapors which it dissolves from the air. The atmosphere, normally composed of oxygen and nitrogen, contains vast quantities of ammonia, carbonic, nitrous, and nitric acids, besides other gases and vapors which arise from the number of chemical phenomena which are ever taking place on the surface of the earth. The principal of the *abnormal* gases is *carbonic acid*—a gas which escapes in enormous quantities from volcanic districts, and which results also from respiration, from the combustion of fuel, and decay of organic matter and vegetal growth generally, on the surface of the earth. Though analysis detects only about one thousandth of this gas in the air, still when the total bulk of the latter is taken into consideration, the entire weight of carbonic acid disseminated in it is enormous, averaging more than *five billions of tons!* The air likewise contains much *ammonia* and vapors of the oxides of nitrogen, besides other unknown gases and vapors, which escape from decomposing animal and vegetal matter.

All the gases which have been detected in atmospheric air are exceedingly soluble in water; hence it follows, that rain-water, as it descends through the lower strata of the air, must become to a great extent impregnated with these gases. LIEBIG has shown that even snow contains much ammonia, and recently in some rain-water, collected on Brighton Downs, MEDLOCK detected this gas, and also traces of the acids of nitrogen, which had probably resulted from the oxidation of a portion of the volatile alkali. It is, therefore, evident that water as it falls from the clouds, whether in the form of snow or rain, is not absolutely pure, but contains much carbonic acid and ammonia. Probably traces of other gases, which have hitherto eluded detection, are likewise present. Not only is ammonia present in snow and in rain, but HORSFORD even detected it in large quantities in the ice from the Glacier de Boisson, at a height of twelve thousand feet above the level of the sea; and MEDLOCK has found marked quantities of this volatile alkali in the purest and most transparent masses of ice from the Wenham Lake in

America. The presence of ammonia in rain-water has not long been known; and it is one of the main causes of the fresh and invigorating influence of it upon the vegetal creation.

SURFACE WATER.—Rain-water is a very powerful solvent of certain ingredients of the soil, such as sulphate of lime, chloride of sodium, and magnesian salts; but when saturated with carbonic acid, as is ordinarily the case, its solvent properties are remarkably increased. For example, ordinary water, free from carbonic acid, will not dissolve more than a grain of chalk per gallon; but when saturated with that gas, the same quantity will dissolve upwards of two hundred grains. In like manner it is found that carbonate of magnesia, which is almost entirely insoluble in ordinary water, will dissolve in water impregnated with carbonic acid in very considerable quantity. Hence, in addition to the alkaline chlorides and sulphates, and sulphate of lime, nearly all spring-waters are found to contain carbonates of lime and magnesia, which are held in solution as bicarbonates by the carbonic acid derived from the soil and atmosphere. Certain of the mineral constituents impart to water its *hardness*. These are the salts of lime and magnesia. By the hardness of a water is understood the power it possesses of decomposing soap; and according to the quantity of soap decomposed by a given quantity of water before the remaining soap becomes available as a detergent, so is its relative hardness. The sulphates, chlorides, and nitrates of lime and magnesia give to the water the so-called *permanent* hardness, while the carbonates, which are held in solution by excess of carbonic acid, impart to it its *temporary* hardness, or that which it loses by boiling.

The waters of rivers, from which the greater number of English cities and towns obtain their supplies, contain the above-named mineral constituents in quantities varying according to the composition of the soil over which they flow. In the water of streams which have their sources in the primitive rock formations, as, for instance, the rivers Dee and Don, there is found only from two to eight grains of mineral constituents per gallon. The water of the Trent, which flows through a *selenitic* district, contains about sixty grains of sulphate of lime; while in the water of the Thames, which is derived from, and flows over a chalk formation, there are only about three grains of sulphate, and from eight to ten grains of carbonate of lime per gallon. For the sake of comparison, and in illustration of the above statement, the analyses of the Thames, Trent, Dee, and Don are given:—

	Thames water.	Trent water.	Dee water.	Don water.
Carbonate of lime, ...	10·80	0.32	0·85	2·23
Sulphate of lime,......	3·00	21·55	0·12	0·13
Nitrate of lime,.......	0·17	—	—	—
Carbonate of magnesia,	1·25	5·66	0·36	1·07
Chloride of sodium, ...	1·80	17·63	0·72	1·26
Silica, ...	0·56	0·72	0·14	0·52
Iron, alumina, ...	0·27	0·50	0·06	0·27
Phospate of lime,.....	trace	trace	trace	trace
Organic matter, ...	2·36	3·68	1·64	3·06
	20·21	50·06	3·89	8·54
Hardness,.......	14.00	26·50	1·50	3·00

From the preceding analyses it is evident that the proportions of mineral constituents are, in a great measure, dependent upon the nature of the soil over which the water flows. Although the opinions of chemists differ widely regarding the hygienic effects of an access of the mineral constituents in water, the Editor is inclined to believe—and this opinion almost universally prevails—that so long as the proportion does not exceed thirty grains per gallon, they are decidedly more beneficial than injurious. The sense of taste is perhaps the best guide; and so long as preference is given to a water containing mineral matter to such as are almost entirely free therefrom, it may be assumed that such waters are the best for general purposes.

These remarks apply equally to the waters derived from wells. Indeed, in all the water supplied for man's use there are found the above-mentioned mineral constituents. Are they there for no purpose? Would Nature contaminate water with constituents injurious to health? It has been already mentioned that such waters as contain a certain proportion of mineral constituents, are much more refreshing and agreeable to the taste than those in which they are absent. The remarkable investigations of modern chemists have shown incontestably that a certain proportion of mineral elements in food is absolutely necessary for the due performance of the vital functions. In milk, man's natural food, there are all the elements necessary for the formation of the body—phosphate of lime for the formation of bone; salts of soda to aid in the formation of the gastric juice, and to give fluidity to the blood; casein to form the flesh; and butter to produce fat. In all the cereal grains and in the vegetals which constitute the chief food of graminivorous animals and of man, there are found the *same* mineral constituents which occur in water—*man's natural drink*. Who, then, can deny the value of mineral constituents in the water of wells and rivers? When in very large excess, as in the *shallow* well-waters of London—an exception to the rule—they may, perhaps, tend in some measure to derange the digestive organs of delicate persons, especially of those who have been accustomed to the use of softer water—that is, such as contains less earthy salts—for dietetic purposes; but in most cases in which hard waters are found to disagree, the objectionable effects may, in all probability, be ascribed with greater truth to *organic* impurities than to the actual *mineral* constituents. Having thus briefly alluded to the physiological effects of the mineral constituents of water, it becomes necessary to enter more fully into the nature of the more abnormal *organic* contaminations to which the water of wells and rivers is exposed, since on these is essentially dependent the hygienic character of the water—its fitness for domestic purposes.

NATURE OF THE ORGANIC MATTER CONTAINED IN WATER.—All river and well waters contain more or less of organic matter, which is acknowledged to be a predisposing cause of disease. The separation of these impurities from water is a problem of high scientific interest, and one that has engaged the attention of all the eminent chemists of the day.

The great importance of this subject in a sanitary point of view renders it necessary to enter into detail regarding it:—

1. The source of organic matter.
2. The nature of the decomposition it undergoes.
3. The means of destroying the organic matter and rendering the water pure and wholesome.

1. *The Source of Organic Matter.*—A river is the natural drain of the country and towns through which it flows, and the organic matter the water contains must necessarily be derived from the three following principal sources:—

From the sewage of towns; from the surface drainage of manured and cultivated lands; and from the decay of the aquatic plants and animals which inhabit the streams.

The sewage of towns consists mainly of the urine and fœces of man and animals, the refuse of gas-works and numerous manufactories, which are diluted with the refuse water which has been used for domestic and manufacturing purposes. The Thames, which may be taken as a type of other rivers, before it reaches London drains an area of four thousand square miles, and receives in its course the sewage of towns containing upwards of seven hundred thousand inhabitants. It flows, moreover, through a richly cultivated country, from which it derives vast quantities of organic matter. It is further contaminated with the products resulting from the decomposition of aquatic plants and animals. Hence it is obvious that the water of the Thames, even before it reaches Teddington lock, must be most seriously contaminated with putrefactive organic matter. That much of the organic matter which enters the river is spontaneously decomposed is undoubted, otherwise the river would be little better than a filthy sewer; but that a vast quantity remains in solution in the water as now supplied to the inhabitants of London, is equally a demonstrable fact, as will be seen by the analyses and experiments detailed in the following pages.

Most, and indeed all the companies who take their supply from the Thames, filter the water through sand and shingle previously to pumping it into the mains. By this means most of what exists in it in the form of undissolved or *mechanically suspended particles* is removed, and the water is consequently to some extent improved in appearance. But the greater part of the organic matter is *dissolved* in the water, and is not separated by mere filtration. That much organic matter exists in the present supply is evident from the decided color which the water possesses. This is also the case with the Pike water at present supplied to Liverpool.

If a tall tumbler be filled with any of the water now supplied to London, Liverpool, Manchester, and other towns, and placed on a sheet of white paper, the water will be seen to possess a yellowish or brownish tinge, occasioned by *the organic matter which is held in solution.* The removal of this organic matter, which is doubtless a fertile source of disease in those who daily drink it, is a problem of the highest interest to solve, and one to which MEDLOCK has devoted several years in the hope of its elucidation. Accident in some measure led him to follow out an inquiry into this subject, which promised to lead to most important results, and the Editor deems the circumstances which suggested this investigation worthy of being recorded; especially as the results arrived at by accurately conducted experiments are not only of high scientific interest in themselves, but, practically applied, are of great hygienic and national importance.

In September, 1856, he was requested by the directors of the Amsterdam Water Company to analyse several samples of water from the city of Amsterdam. Complaints had been made of the water by several of the inhabitants. It possessed a peculiar *fish-like* smell; and although perfectly transparent and colorless, and free from the slightest chalybeate taste, it was found, after standing some time, to deposit a reddish-brown sediment, which coated every vessel in which the water was placed.

The service-pipes being of iron, the deposit was assumed to consist of the sesquioxide, resulting either from the decomposition of a protosalt of iron in solution, or from the attrition of the iron pipes through which the water was conveyed.

It may be observed that Amsterdam is supplied with water from the *Dunes*—sand-hills—in the neighborhood of Haarlem. Trenches, five miles in length, have been dug on the sides of the hills, to intercept the rainfall. The water is conveyed to a large reservoir, whence it flows to the filterbeds at the works, and is there filtered through four feet of filtering medium, consisting of pebbles, shells, and fine sand. After filtration it is pumped up an iron standpipe one hundred and fifty feet high, and conveyed thence by iron mains to Amsterdam, a distance of eighteen miles.

Five samples of the water were sent for analysis—one from the works *before the water came in contact with iron*; the other four from various standpipes in the city.

In the water from the works, before it came into contact with iron, the quantity of iron oxide, alumina, and phosphates amounted to 0·95 grain per gallon. In the analysis of the four other samples, *after passing* through eighteen miles of iron pipes, the quantities were reduced in the several determinations to 0·09, 0·07, and 0·07 grain, and in the fourth sample to an unweighable trace. Thus, instead of taking up an additional quantity of iron oxide from the mains and service-pipes, the water was found actually to have lost nearly the whole of the iron which it previously held in solution; but, notwithstanding the almost entire precipitation of the iron actually in solution in the water which had passed through iron pipes, it formed the objectionable red deposit on standing, while the water from the works, holding in solution nearly half a grain of iron oxide per gallon, formed no such deposit: therefore it was, *à priori*, to be assumed that the red deposit could not consist of oxide of iron, and consequently it appeared necessary to examine this deposit very carefully both chemically and microscopically. The precipitate from ten gallons of water was collected in a porcelain capsule, evaporated to dryness on a water-bath, and heated subsequently in an air-bath to 248° Fahr., until it ceased to lose weight. On ignition, the precipitate *charred* and was almost entirely consumed, leaving only a minute quantity of ash, consisting of silica, alumina, iron oxide, and carbonates of lime and magnesia.

The small quantity of this deposit at command did not admit of a quantitative analysis. The deposit having been found to consist almost entirely of organic matter, a portion of it, which had been separated from one gallon of water, was examined under the microscope, and was seen to consist of the filaments of dead and decaying algæ, confervæ, and other microscopic plants in various stages of decay, and varying in color, like autumnal leaves, from green through pale-yellow, orange, red, brown, dark-brown to black. Many of the fibres retained a perfectly organized structure, and in some the spores, by which these plants are propagated, were distinctly visible. Amongst these plant remains were numerous silicious tubes, which had probably invested the delicate filaments of the algæ while living.

It appeared highly important to determine the *cause* of the precipitation of the organic matter from the water which had been in contact with the iron pipes; and in the hope of elucidating this interesting question MEDLOCK proceeded to Amsterdam to inspect the source of supply and the works. As anticipated, the Dune canals were found to be actually choked up with aquatic plants, and at the sides and wherever the current was sluggish were large masses of dead algæ floating on the surface. The sand at the bottom, originally very white and pure, was blackened to some depth by decaying vegetal matter, and, when disturbed, numerous bubbles of fetid marsh gas escaped.

The water had the peculiar fish-like smell of the masses of *flab—ulva intestinalis*—floating on the surface. The stones on the sides of the canals, the hurdles placed to keep up the banks, floating pieces of stick, and indeed every *solid* body with which the water came in contact, were coated with a reddish-brown deposit, similar to that which was found to separate from the filtered water in Amsterdam. *This deposit was observed to be particularly abundant near the iron sluice gates.* A pipe from one of the mains in the city was examined at the same time, and found to be coated on the inside with a thick slimy deposit of vegetal remains, which presented under the microscope an appearance exactly similar to that of the deposits above alluded to.

Remembering the important fact established by SCHÖNBEIN, that copper and platinum in a finely divided state have the property of converting ammonia into nitrous acid; and MEDLOCK having demonstrated that *lead* in any form possesses a similar power—it occurred to him that if the same property were possessed by iron, it would throw some light on the separation of the organic matters from waters which are placed in contact with that metal. SCHÖNBEIN, however, states that iron, before it produces a similar oxidizing effect on the ammonia, requires to be heated to redness. But in the course of an extensive series of experiments, it has been found that iron pyrophorus *instantly* transforms ammonia into nitrous acid; and in pursuing the inquiry further, it was found that strips of sheet iron placed in water containing ammonia or organic matter capable of yielding it, act almost as energetically as the metal in a finely-divided state.

Having proved that metals possess this remarkable power of oxidizing ammonia, and converting it into nitrous acid, and, bearing in mind the extraordinary oxidizing power of this acid, even when present in minute quantities, it appeared to MEDLOCK that he had arrived at a simple and effectual means of depriving water of all organic impurities by thus accelerating a natural process of decay. The facts just mentioned appeared to merit a thorough investigation, and the results arrived at will sufficiently prove that he did not, in the first instance, attach too much importance to them. In order to study the action of iron upon the Amsterdam water, he submitted to analysis a quantity of this water which *had never been in contact with iron*, and at the same time he immersed several coils of iron wire in two gallons of the same water. The water in which the iron wire was placed was perfectly bright and free from color, and had nothing visible in mechanical suspension except a few of the siliceous tubes already alluded to. The experiment was made in four open glass bottles. A series of remarkable phenomena were observed. In five minutes a faint white cloud was seen radiating from the coil of wire, and descending in the form of a parachute. In half an hour the cloud had increased in density, and the water became opalescent. In six hours the cloud assumed a brownish color, and there was a brown deposit at the bottom of each of the bottles. The cloud continuing to increase during forty-eight hours, assumed more and more a flocculent character, and a reddish color, exactly like the deposit from the water which had flowed through the iron pipes. The water was now filtered through fine Swedish filter-paper and submitted to analysis, and a portion of the deposit examined under the microscope. The latter consisted of the remains of algæ, each separate flock having a siliceous tube as a nucleus. The remainder of the deposit was burned, and the ash found to consist of oxide of iron, silica, and the carbonate of lime and magnesia.

The following are the analyses of the water before and after being in contact with iron:—

	I. Water from the Dune canals.		II. Same water, having been in contact with iron forty-eight hours.
	Grs. per gal.		Grs. per gal.
Sulphate of lime,.............	3·70	....	3·68
Chloride of sodium,............	4·10	....	4·01
Carbonate of lime,............	5·60	....	3·20
Carbonate of magnesia,.......	3·97	....	1·30
Silica,......................	0·16	....	trace
Iron, alumina, and phosphates,	0·95	....	trace
Matter, volatile on ignition—so called organic matter,......	2·10	....	trace
	20·58	....	12·19

By these analyses it is seen that the 2·10 grains of organic matter contained in the water *were decomposed or thrown down by contact with iron.* The water, thus purified, no longer had the unpleasant fish-like taste and smell which had marked its previous contamination.

A portion of the water which had been in contact with the iron wire was rendered slightly alkaline by pure alcoholic potassa, evaporated to dryness, and the residue tested for nitrous acid. The paper became instantly blue from the liberation of a trace of the nitrous acid formed by the oxidation of ammonia, and which had been instrumental in destroying the organic matter.

In the residue of the water which had *not* been in contact with iron and still containing its organic matter, no indication of nitrous acid could be obtained.

The Amsterdam water, the water of the Thames, and indeed that of nearly all other rivers, contain much organic matter, which may be divided into two classes —*nitrogenous* and *non-nitrogenous*. The latter, consisting of carbon, oxygen, and hydrogen, may be represented by the general formula—n (CHO); and, when no longer under the mysterious influence of the vital force, are rapidly resolved into carbonic acid and water. The nitrogenous class being chiefly of animal origin, and composed, in addition to the above-mentioned elements, of nitrogen, sulphur, and phosphorus, may be represented by the general formula—n (CHONSP). Now, when animal matter decays, and when dissolved in water, decomposition proceeds very rapidly; beside carbonic acid and water other and very offensive products are eliminated. As a general rule, the carbon unites with oxygen to form carbonic acid; and with hydrogen, to form marsh gas or carbide of hydrogen; hydrogen and oxygen unite to form water; nitrogen and oxygen with hydrogen to form ammonia; sulphur with hydrogen to form sulphide of hydrogen; phosphorus with hydrogen to form phosphide of hydrogen.

The latter two are exceedingly offensive to the sense of smell, and are, moreover, highly poisonous. Thus in the spontaneous decomposition of the organic matter contained in water there are produced carbonic acid, carbide of hydrogen, ammonia, sulphide of hydrogen, and phosphide of hydrogen. These are the *recognized* compounds; but when it is borne in mind that the gaseous emanations of decomposing animal matters are infinitely more offensive to the sense of smell and injurious to health than any of the gases above mentioned, or of any combination of them, it can only be concluded that the effluvia of decaying organic matter contain other constituents, of which the true character has not yet been determined. Thames water, if allowed to stand in an open vessel for a few days in warm weather, acquires a very offensive odor, arising from the decomposition of the animal and vegetal matter which it holds in solution.

This water, notwithstanding, is considered by maritime authorities to be the very best for the use of ships' companies. On board ship the water is stored in wooden casks, which are placed low down in the hold. During the first week or fortnight, according to the temperature of the atmosphere, the water ferments, evolves a quantity of gas of offensive odor, and deposits a copious brown sediment. The water gradually ceases to smell badly, becomes bright and sparkling, and will then keep fresh and sweet for an indefinite length of time. In other words, it loses by a natural process of decay, the whole of its *putrescent impurities*. In vessels of war, and in most of the large steamers, tanks of iron have been substituted for casks of wood for storing the water necessary for the use of the passengers and ship's company. In iron tanks Thames water evolves *no offensive gases*, but becomes much purer than when stored in wood, and deposits a more copious brown sediment, which turns red on exposure to the air. The gases produced in the wooden casks are said to be slightly luminous in the dark, and to explode when a lighted candle is incautiously placed near the bung-hole, when the plug is removed. The luminosity is due to phosphide of hydrogen, and the explosive character of the gases to carbide of hydrogen.

As the organic matter was found to be so effectually removed by iron from the Amsterdam water, MEDLOCK instituted a series of experiments upon the water of the Thames. The water operated upon was that supplied to his laboratory by the Grand Junction Company. On placing some of this in contact with iron in glass bottles, precisely similar phenomena were observed as in the case of the Amsterdam water, but the deposit was *blacker*, and was formed more quickly. The next step in the investigation was to test the water before and after contact with iron for the great destroying agent, NATURE'S SCAVENGER, *nitrous acid*. The residues of six separate gallons of the water were examined for nitrous acid as follows:—Each residue, mixed with half an ounce of water was introduced into a Florence flask, fitted with a cork and long funnel tube. In the neck of each flask was placed a slip of bibulous paper, moistened with starch paste and iodide of potassium. Through each funnel tube was added half an ounce of dilute sulphuric acid, one part strong acid, and nine parts water, to liberate the nitrous acid, if present; but no indication of that gas was found, as the test papers remained perfectly white. Six other gallons of water drawn at the same time, were placed in open bottles, with two ounces of fine iron wire, and left for forty-eight hours. The waters were then filtered from the deposits, evaporated to dryness, and tested for nitrous acid in a manner similar to the preceding, and with the following results:—

Experiment 1.—Paper becomes blue in ten minutes.
" 2.—Paper becomes blue in five minutes.
" 3.—Paper becomes blue in four minutes.

As it appeared probable that the nitrous acid liberated by the sulphuric acid might remain in solution, and in consequence not instantly affect the test-paper, in experiments with the residues of the other three gallons of the water *hot water* was used, and an acid of double strength. In each of these experiments the test-paper became blue in a few seconds.

These results prove beyond a doubt the production of nitrous acid by the action of iron upon the nitrogenous compound contained in the water. The Editor submitted masses of the Pike water to a similar treatment, and found results that confirmed in every respect those attained by MEDLOCK. Why is not this plan of purification adopted by the Water Committee in Liverpool?

EXAMINATION OF THE BROWN DEPOSIT PRODUCED BY IRON.—The brown deposits from three separate gallons of Thames water were collected in porcelain crucibles, and dried at 248°, till they ceased to lose weight. When thoroughly dried they weighed as follows:—

NO. I.	NO. II.	NO. III.
4·4352 grains.	4·4243 grains.	4·4350 grains.

They were then separately analysed with the following results centesimally:—

	I.	II.	III.
Organic matter	22·92	24·87	23·87
Sesquioxide of iron	65·36	63·20	64·39
Carbonate of lime	11·11	11·04	11·20
Carbonate of magnesia	traces	trace	—
Silica	0·59	0·49	0·53
Loss	0·02	0·31	0·01
	100·00	100.00	100.00

In order to arrive at a correct knowledge of the action of iron upon Thames water, **Medlock** made a series of daily determinations of the mineral residue and organic matter in the water supplied to his laboratory, with the following results:—

	Solid residue. Grs. per gallon.	Organic matter Grs per gallon
Jan. 4th, 1857	20·867	2·248
Jan. 5th, 1857	19·573	1·740
Jan. 6th, 1857	21·159	1·424
Jan. 7th, 1857	20·127	1·401
Jan. 8th, 1857	21·452	3·249
Jan. 9th, 1857	20·374	2·756
Jan. 10th, 1857	20·920	3·062
Average	20·638	2·268

At the same time as the water was drawn for the last analysis, he placed three separate gallons in wide-mouthed bottles.

Into the first gallon was put a coil of fine iron wire, weighing half an ounce. After standing two hours the water was filtered, and on being analysed in the usual way, gave—

Solid residue,....................17·372 grains.
Organic matter,.................. 1·232 do.

A second gallon with one ounce of wire for two hours gave—

Solid residue,....................16·693 grains.
Organic matter,.................. 1·170 do.

A third gallon with eight ounces of wire for two hours gave—

Solid residue,....................13·182 grains.
Organic matter,.................. 0·950 do.

In other experiments, too numerous to detail, the water was exposed to the action of a *large surface of iron* from twelve to forty-eight hours; and as a general result it was found that by allowing water to remain in contact with a large surface of iron for about twelve hours, every trace of organic impurity was destroyed, or converted from the soluble to an insoluble condition, in which state it admitted of being effectually removed by ordinary filtration.

After the preceding details on the nature of the organic impurities contained in ordinary well and river water, the offensive gases arising therefrom, and the functions of the numerous microscopic plants and animalcula which are contained in them, it now remains to describe the means that **Medlock** has adopted for placing the results of his discoveries at the service of the public.

Practical Application of the foregoing Principles.—It has been proved by numerous trials with Thames water, sewage, and water artificially contaminated by mixing therewith sulphide of hydrogen, sulphide of ammonium, and urine, that however impure a water may be, it can be rendered perfectly pure and wholesome to drink by merely allowing it to remain in contact with a large surface of metallic iron for twelve or twenty-four hours, and then filtering through well-washed sand; or, better still, through a mixture of about one part animal charcoal and four parts sand.

The plan above stated is applicable to the purification of the supply of water to towns, as well as to small quantities for domestic and manufacturing purposes. To brewers, dyers, starchmakers, soda water and lemonade manufacturers, *et cetera*, a supply of water free from color and organic impurities is an essential requisite; and the Editor after long and careful study of the numerous processes recommended for purifying water, prefers the one above detailed, as being at once the most simple, easy, and effectual.

The following table exhibits in round numbers the degrees of impurity in water, used for the supply of towns in England, Scotland, *et cetera*, each degree being equal to one grain per gallon—

Distilled water	0°
Loch Katrine	2·0
Dee—Aberdeen	4·0
Tay—Perth	5·5
Dumfries	7·0
Gorbals	8·0
Leven	8·5
Clyde	9·5
Tyne—Newcastle	11·0
Tweed—Coldstream	11·5
Seine—Paris	12·0
Liverpool well, purest	13·0
Glasgow " "	15·0
Kilmarnock	15·0
Thames—1854	15·5
" —1851	21·0
Glasgow well, most impure	96·0
Liverpool well, "	417·0

Disease occasioned by the Organic Impurities of Water.—Dr. **Hassall** remarks—In proof that water highly charged with decomposing organic matter frequently gives rise to severe and fatal diseases, often of an epidemic character, one is able to produce abundance of evidence. To occasion these effects, no doubt the organic matters, animal or vegetal, resolve themselves into carbide, sulphide, and phosphide of hydrogen, cyanides, *et cetera*, as well as other lethal products, and these disarrange the whole functions of the body. To enter more minutely into this part of the subject would be out of place in a technological work.

Disease occasioned by the Metallic Impurities in Water.—The Editor has known most serious illnesses to arise from water containing lead. Many hard as well as soft waters act injuriously upon lead, consequently, as a general rule, water should never be stored in cisterns of this metal. Why use lead when one can have slate cisterns and enamelled iron pipes? A gentleman and his family residing in the neighborhood of Liverpool were constantly ill, but whenever they left home they recovered. The water was supposed to be the cause, and was tested from time to time, and pronounced good. The amount of lead was small, and had been overlooked—as is very often the case with inexpert analysts. On examination of several gallons of the water—it was a remarkably soft water—lead was detected. The Editor recommended slate cisterns and enamelled iron pipes, and from that day to this all the ill effects of the water disappeared.

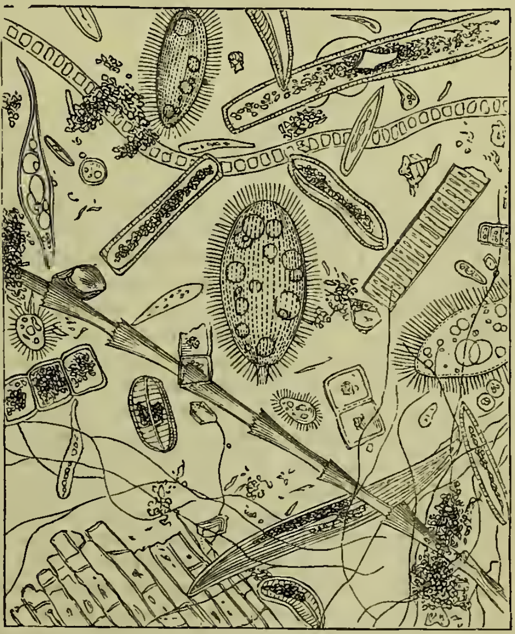
Microscopic examination of Water.—Most well and river waters, when allowed to stand in an open vessel for several days, especially in warm weather, deposit a sediment more or less copious, in which may occasionally be discovered, by means of a microscope, a vast number of the lower forms of animal and vegetal life, which have been made the subject of special study by several able microscopists, and especially by Drs. HASSALL and LANKESTER. Much misapprehension, however, appears to prevail regarding the extent to which these lower forms of organic life occur in water. In works treating on this subject, it is usual to group a large number of these objects together in a circular drawing, which convey the impression, and are generally understood to represent the animalcula contained in a single drop of water. Nothing, however, can be more erroneous, and nothing more calculated to convey false notions regarding the character of the water supplied to the public.

It appears to be a law of nature, that wherever the conditions of life exist, there life will manifest itself in forms suited to the circumstances. If a portion of earth be brought up from the deepest mine, and exposed for some time to the combined influence of heat, light, and moisture, various forms of vegetal and animal life will appear, even if the soil be entirely excluded from contact with the surrounding atmosphere. In the water of rivers containing animal and vegetal matter in a state of decay, are presented all the conditions of life; and hence the numberless forms of the lower organisations which are met with. That these are injurious to health, no one can venture to affirm; but their presence may form, to some extent, an index of the quantity of putrefactive organic matter which may be present. In cases where it is necessary to examine a water microscopically, the following is the plan recommended by the Editor:—

About a quart of the water to be examined should be placed in a conical glass vessel, very narrow at the bottom, in shape something like a tall champagne glass, and covered over with paper. After remaining at rest some hours, a slight deposit will generally be observed at the bottom; and in this deposit will often be seen numerous small animalcula moving about with wonderful rapidity; these have been named by naturalists *Cyclops quadricornis.* They are particularly abundant during the summer in river waters containing much organic matter. Other crustacea are also abundant, amongst which may be mentioned various species of Daphnia, which, by their number, often give a marked yellow color to water. Of radiate animals, the hydra and other forms of zoophytes are frequently present. The fresh water sponge—*Spongia fluviatilis*—frequently occurs in great abundance. Numerous lower forms of the vegetal kingdom often abound in river waters, especially in those of shallow streams. These belong chiefly to families Confervaceæ, Dismidieæ, Diatomaceæ, and Fungi. Many of these lower organisms are beautiful objects under the microscope, and well worthy of the attention of all lovers of nature. Space will not allow of any detailed description of the almost numberless species found in water; they have been only briefly alluded to with the view of pointing out the fact, that when they occur in water used for dietetic purposes, they must be regarded as a proof of the presence of dead and decaying organic matter, and must not be looked upon as the only kind of contamination of the water. Their function appears to be to destroy the numerous organic matters which are present. To examine well the deposit formed in the conical glass, the clear water should be siphoned off, and a portion of the deposit placed in the field of the microscope—a quarter-inch glass is perhaps the best for such observations.

Dr. HASSALL examined several specimens of water, both upwards and downwards in the course of the river Thames from London, and they brought to light the singular and important fact that Thames water, from Brentford in one direction to Woolwich in an opposite, swarms with living productions, principally of the genus *Paramecium,* and of one species of this genus *P. chrysalis* of EHRENBERG.

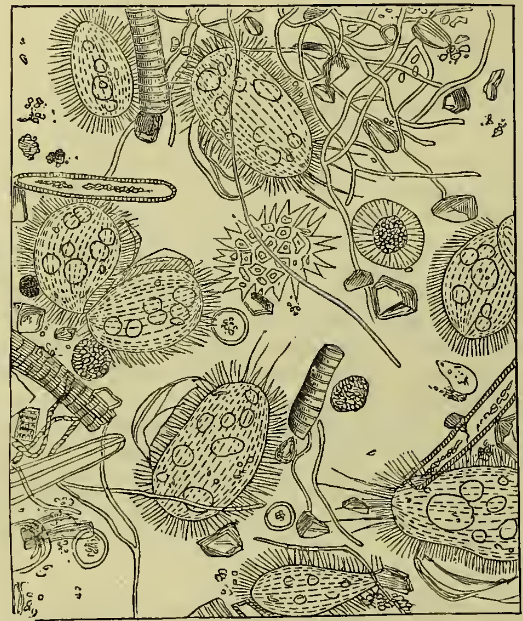
Fig. 613.



The engraving exhibits the principal animal and vegetal productions contained in the Thames water at Richmond, drawn with the camera lucida, and magnified two hundred and twenty diameters.

The subjoined cut exhibits the more remarkable vegetal and animal productions found in the water of the Thames at Waterloo Bridge.

Fig. 614.



Color of Water.—In rivers the impurity of water is frequently visible to the eye. It is often of a red color, as it flows through rocks of red marl which contain much oxide of iron in their composition. It descends milky from the glaciers of Iceland and the slopes of the Andes, because of the white earth it holds in suspension. It is often grey or brown in the muddiest English rivers. It is always brown when it issues from boggy lakes, or runs across a peaty country, as at Rivington Pike. It is occasionally black to the eye when the amount of vegetal matter is excessive, as in the Rio Negro of South America; and it is green in the geysers of Iceland, in the Swiss lakes, among the islands of the South Sea, and around Great Britain and Ireland. Only in clear and deep water, like those of the Bay of Naples, and in parts of the Pacific, where minute objects may be seen on the bottom some hundreds of feet down, is the real blue color natural to water in large masses distinctly perceptible. This is the deep blue which is seen in the *grotto azzura* of the island of Capri, in the Bay of Naples, and in the deep indigo waters of some parts of the Mediterranean and Adriatic seas.—*Johnston.*

THE ADDITION OF CHEMICAL AGENTS TO WATER.—This head includes several proposed methods of purifying water, which consist in the addition of certain chemical agents to this liquid, by which its composition is altered.

Addition of Alum.—In England, as well as in France, a popular method of clearing muddy water is to add a few grains of powdered alum to it; two or three grains are usually sufficient for a quart of water. This process is called *alunage de l'eau;* and ARAGO states, that when practised on the Seine water, it causes the mud to agglomerate in long thick striæ, which are very quickly deposited. The theory of the process appears to be this:—The alum decomposes the bicarbonate of lime, and gives rise to the formation of sulphate of lime, which, with sulphate of potassa, remains in solution, while carbonic acid is evolved, and hydrate of alumina being precipitated in a flocculent form, carries with it various mechanical impurities.

$$\underbrace{KO, SO_3 + Al_2O_3, 3SO_3}_{\text{Alum—dry.}} + \underbrace{3(CaO, 2CO_2)}_{\text{Bicarbonate of lime.}} =$$

$$\underbrace{6CO_2}_{\text{Carbonic acid.}} + \underbrace{KO, SO_3}_{\text{Sulphate of potassa.}} + \underbrace{3(CaO, SO_3)}_{\text{Sulphate of lime.}} + \underbrace{Al_2O_3}_{\text{Alumina.}}$$

This method, then, is a kind of mechanico-chemical one. It clears the water, but at the same time alters its chemical composition, and by converting bicarbonate into sulphate of lime, augments the hardness of the water.

Addition of Caustic or Carbonated Alkalies.—Caustic alkalies, added to water holding in solution bicarbonate of lime, saturate the excess of carbonic acid, throw down carbonate of lime, and leave an alkaline carbonate in solution. If soda be the alkali used, the results will be as follows:—

$$\underbrace{CaO, 2CO_2}_{\text{Bicarbonate of lime.}} + \underbrace{NaO}_{\text{Soda.}} = \underbrace{NaO, CO_2}_{\text{Carbonate of soda.}} + \underbrace{CaO, CO_2}_{\text{Chalk.}}$$

If an alkaline carbonate be employed, all the earthy salts—calcareous and magnesian sulphates, chlorides, bicarbonates, and carbonates of the earths—are precipitated, while alkaline sulphates, chlorides, and bicarbonates which do not communicate hardness to water, are left in solution. If carbonate of soda be employed, its reaction on sulphate of lime and chloride of magnesium will be as follows:—

$$\underbrace{CaO, SO_3}_{\text{Sulphate of lime.}} + \underbrace{MgCl}_{\text{Chloride of magnesium.}} + \underbrace{2(NaO, CO_2)}_{\text{Carbonate of soda.}} =$$

$$\underbrace{NaO, SO_3}_{\text{Sulphate of soda.}} + \underbrace{NaCl}_{\text{Chloride of sodium.}} + \underbrace{CaO, CO_2}_{\text{Carbonate of lime.}} + \underbrace{MgO, CO_2}_{\text{Carbonate of magnesia.}}$$

Addition of Lime.—A few years ago, Professor CLARK of Aberdeen took out a patent for the purification of water. His process consists in the addition of caustic lime to water, by which the bicarbonate of lime held in solution is decomposed; the caustic lime saturates the excess of carbonic acid, and forms carbonate of lime, which is precipitated.

$$\underbrace{CaO, 2CO_2}_{\text{Bicarbonate of lime.}} + \underbrace{CaO}_{\text{Caustic lime.}} = \underbrace{2(CaO, CO_2)}_{\text{Carbonate of lime.}}$$

The Editor believes the process of CLARK to be *virtually impracticable on the large scale,* while its efficacy is but slight.

It must be remembered that this mode affects the bicarbonate of lime, not the more troublesome earthy salts, such as the sulphates and chlorides, on which the hardness of spring waters mainly depends. The difficulty of mixing lime and water, in definite proportions, on the large scale, must be obvious to every one. If too much be employed, the companies would supply their customers with *lime-water!* If too little, the bicarbonate of lime would not be completely destroyed, and the process would be a failure. Altogether, the difficulties of carrying out the process will ever prevent its adoption on a large scale.

Addition of Oxalate of Potassa.—Mr. HORSLEY of Cheltenham, some years ago, took out a patent for a new method of preventing incrustations in boilers, and also for depurating, filtering, and otherwise rendering water more fit for drinkable and other purposes. When sea-water is taken for generating steam, he purifies it by employing oxalate of potassa and ammonio-phosphate of soda; and the proportions he uses for the water of the British Channel are about two drachms of oxalate of potassa to about two ounces of the ammonio-phosphate of soda for every gallon. When his object is to februate and soften hard water, he employs such substances as are capable of decomposing the calcareous salts, such as calcined or caustic baryta, or baryta water, phosphate of soda, silicate of potassa, oxalic acid, or the oxalates, and caustic strontia, or strontia water; but he gives the preference to oxalate of potassa. He first ascertains the degree of hardness of the water, and then adds the requisite quantity of oxalate of potassa, by which an oxalate of lime is precipitated; and there remains in solution, instead of the lime thus displaced, a carbonate, sulphate of potassa, or chloride of potassium, as the case may be, and the water is purified and fit for use.

The following equation explains the reaction of oxalate of potassa; the salt is assumed to be neutral on bicarbonate and sulphate of lime:—

$$\underbrace{\mathrm{Ca\,O,\,2\,CO_2}}_{\substack{\text{Bicarbonate}\\ \text{of lime.}}} + \underbrace{\mathrm{Ca,\,SO_3}}_{\substack{\text{Sulphate}\\ \text{of lime.}}} + \underbrace{\mathrm{2\,(KO,\,O)}}_{\substack{\text{Oxalate}\\ \text{of potassa.}}} =$$

$$\underbrace{\mathrm{2\,(Ca\,O,\,O)}}_{\substack{\text{Oxalate}\\ \text{of lime}}} + \underbrace{\mathrm{KO,\,2\,CO_2}}_{\substack{\text{Bicarbonate}\\ \text{of potassa.}}} + \underbrace{\mathrm{KO,\,SO_3}}_{\substack{\text{Sulphate}\\ \text{of potassa.}}}$$

HORSLEY's patent process does that which CLARK's fails to do: it decomposes all the earthy salts on which the hardness of water usually and mainly depends. But it is open to still greater objections than those that have been raised to the other method. Besides being, like CLARK's, process virtually impracticable, it would prove very expensive, and as regards the metropolitan river-waters, it is quite unnecessary. Moreover, the idea of *physicking* or *doctoring* water, by the addition to it of a poisonous agent, would, if even no other objection existed to this scheme, be quite fatal to it. For though, in the hands of competent persons like Mr. HORSLEY, no possible injury could arise from its use, yet the public would always have some suspicion of water thus treated; and, as a celebrated English engineer observed to ARAGO, water, *like Cæsar's wife, should be above suspicion*, which the Rivington Pike water supplied to Liverpool is not. Liverpool was formerly supplied with spring water from the red sandstone, beautifully cool and refreshing, and free from organic matter. Now the inhabitants are forced by a stubborn water committee to drink a mixture of the *rock* and *surface* water—how the people suffer it is to the Editor a mystery—the latter certainly *blasting its wholesome brother*. The small town of Flint, North Wales, has infinitely better water than is supplied to any of the principal towns of England.

Purification and Filtration of Water.—JOHNSTON says truly, that the water used by a nation or country is an important matter in a well-considered and long-adjusted diet. It by no means follows in all cases, perhaps not even in the majority, that the *purest* water—see *Distilled Water*—is the best for the health of a given family, or for the population of a given district. The bright, sparkling, hard waters which gush out in frequent springs from the chalk and other limestone rocks are relished to drink, not merely because they are grateful to the eye, but because there is something exhilarating in the excess of carbonic acid they contain and give off as they pass through the warm mouth and throat, and because the lime they hold in solution neutralizes or counteracts acid matters in the stomach, and thus acts as a grateful medicine to the system.

On entering upon the purification and filtration of water, it may be stated as an axiom that *the best filter is no substitute for bad water;* still, as various towns throughout the kingdom are supplied with bad water, that is, water containing chemical and mechanical impurities, the Editor deems it necessary to explain to the reader how to remove these wholly or in part, so as to *better* the water. The depuration of water is greatly aided by repose, by which various suspended or mechanical impurities are allowed to subside gradually, and from these the supernatant fluid is drawn or siphoned off. Tanks, cisterns, and reservoirs become therefore important depurating agents. The purification of water by subsidation and decantation is the simplest of all methods of februation; but unfortunately it is a very slow one. It is stated that the water of the Garonne, taken when the river is swollen, does not regain its natural limpidity after a fortnight of perfect rest. The larger particles, of course, quickly deposit, but the finer ones precipitate very tardily. During the time that deposition is occurring, the water is exposed to the air, and consequently undergoes a chemical metamorphosis. The bicarbonate of lime which is dissolved in it parts with a portion of its carbonic acid, and carbonate of lime precipitates:—

$$\underbrace{\mathrm{CaO,\,2\,CO_2.}}_{\text{Bicarbonate of lime.}} = \underbrace{\mathrm{CO_2.}}_{\text{Carbonic acid.}} + \underbrace{\mathrm{CaO,\,CO_2.}}_{\text{Carbonate of lime.}}$$

In this way the atmosphere assists in softening those waters, which owe the whole or a portion of their hardness to the above calcareous salt. The atmosphere, however, is a source of contamination as well as of purification, and it is on this account that the Editor always condemns the use of *surface* water for dietetic purposes. EHRENBERG states that, exclusive of inorganic substances, he has detected three hundred and twenty species of organic forms in the dust of the winds. It is obvious, therefore, that waters which are chemically very pure, must become contaminated by exposure in deposit reservoirs.

What are the best methods of purifying water on a large scale?

The water, says TOMLINSON, used for culinary, domestic, and industrial purposes, is exclusively derived from the rain which falls upon the earth, whether the immediate source of supply be the cistern, the well, the spring, or the river. Rain-water is usually so pure, that the action of the most delicate chemical tests is required to detect any foreign substance in it; so that, if cisterns were formed of proper materials, and the rain fell directly into them in sufficient quantity, no better water could be desired. But as the exposed surface of cisterns is too small to collect rain-water in any quantity, it is usual to discharge into them, by means of gutters and shoots, the water which falls upon the roofs of houses; and, as these are covered with dust, insects, and other impurities collected during dry weather, the rain-water of cisterns is thus contaminated in various ways. In some places the rain-water, collected on the surfaces of extensive roofs and flats, is made to pass through a bed of porous materials on its way to the cistern, and thus the solid impurities are strained and separated before the water is used by the public. Such is the case with the large cistern of the ducal palace at Venice.

Wells may be compared with cisterns; but the channels which discharge rain-water into them are not formed of masonry, brick, or metal, but of the rocks which exist immediately beneath the surface. These rocks may be porous, or may abound in minute fissures, through which the rain-water, sinking through the soil, finds a passage; and being divided into innumerable liquid threads, it dissolves and carries along with it a portion of whatever soluble matter it may encounter. Hence, the water obtained from wells is not rain-water, properly so called; it is usually as clear and limpid, but it contains nearly always certain substances in solution, which vary according as the geological structure of the country differs. The same remark applies to springs: their water is rain-water, which, after having traversed strata of greater or less thickness, is sent up to the surface by the pressure of the water in the neighboring hills or other elevations. The nature and proportion of the impregnation to which spring-water is subjected, depend also on the extent of its transit and the kind of rock traversed. The action of rain-water upon certain kinds of rock leads to the production of mineral springs; and if the water descends to a certain depth in the earth, its temperature will be so much raised by the internal heat, that on reappearing at the surface, it will be as a thermal spring.

In filtering on a large scale, for the supply of a city, for example, the cost and durability of the filter are important considerations. On the great scale of Nature, the rocks which filter the water, as it falls upon the surface of the soil, constitute a vast permanent filter, the durability of which arises from the great extent of superficial or subterranean surface concerned. It might at first view appear to be easy to imitate this natural operation, and pass the muddy water of a river through the porous rock or sand which forms its banks; but this is often an expensive proceeding, on account of want of permanence of an artificial structure so contrived. Toulouse is supplied with water from the Garonne in this way, and it has cost upwards of forty thousand pounds at various times for supplying a city of only fifty thousand inhabitants. The cause of failure in this and other instances arises from the fact already noticed, that when water percolates sand, it deposits its solid impurities to a certain depth between the interstices of the filtering medium, rendering it necessary from time to time to renew the sand. This is illustrated by some experiments conducted by Mr. WICKSTEED. A sand filter which yielded at the rate of ten the first week, yielded nine the second week, six the third week, and only two the fourth week; so that a large natural filter—as this description of filter is called—may go on for some years, yielding a good supply of water, and then gradually diminish it until it ceases altogether. Hence the construction of these so-called natural filters requires much caution on the part of the engineer; and it will always be difficult, if not impossible, to calculate before hand the amount of water which a natural filter proposed to be erected will yield.

A second system of filtration on a large scale consists in the formation of extensive beds of sand of great thickness, resting on beds of gravel, *et cetera.* At intervals of time, from ten to fourteen days, the water is run off; and the filth which had accumulated during filtration is scraped off with a certain thickness of the sand of the filtering bed. Once or twice a year the whole of the sand removed is replaced. This method is costly, and not altogether satisfactory.

Of all the permeable substances used for filtration, animal charcoal possesses in the highest degree the combined mechanical and chemical influence. In addition to its power, in common with other filtering media, of removing suspended or mechanical impurities, it also abstracts from the liquid which percolates it, various *dissolved* bodies, and thus effects a metamorphosis in the chemical composition of the fluid which traverses it. These important properties of animal charcoal have oftentimes led to its use as a filtering medium for water; and hence it is introduced into many of the ordinary domestic water filters. But its deodorizing and decoloring power is soon lost; and, in order to enable it to reacquire its original efficacy, it requires to be re-formed.

There can be no doubt that of all known permeable bodies, the only ones which present all the requisites of filtering media for water on a large scale, are sand and gravel. They are cheap, allow the rapid passage of water through them, and, when *they have been previously well washed,* communicate no taint to the waters which traverse them. Their employment must have been suggested to man by the observation of the numerous limpid springs which are seen in arenaceous districts.

Their action, however, is chiefly *if not entirely* mechanical. They possess little or none of that power of effecting chemical changes on the liquids filtering through them, which animal charcoal possesses in so pre-eminent a degree. Yet, unless several distinguished writers have grossly deceived themselves, sand is not entirely devoid of this chemical influence. Wagenmann, for example, found that when vinegar was filtered through pure quartz sand, the first portion of liquid that percolated was deprived of almost *all its acid;* and the vinegar did not pass through unchanged until the sand had become well charged with acid. The same authority also states that potato-brandy diluted with water, and filtered through quartz-sand, yields at first pure water, then a mixture of water and alcohol deprived of its fusel-oil; and, lastly, the original mixture unaltered. Berzelius filtered a saline solution through a long tube filled with sand, and found that it ran out more or less completely deprived of salt. Matteucci repeated Berzelius' experiment, and confirmed his statement. He filled a tube about twenty-six feet long with sand, and filtered a saline solution through it; and he found that the density of the liquid introduced by the upper aperture of the tube was to that of the liquid escaping from the lower end, as 1·00 to 0·91. But he observed that this difference of density was not always maintained; for, after a certain time, the saline solution becomes as dense at its exit from, as at its entrance into the tube, proving that the decomposition of the saline solution takes place in the first action of contact between it and the particles of sand. But a still more remarkable result, the inverse of the one just stated, was obtained by the last-mentioned chemist, with a solution of carbonate of soda. He filled a tube nearly ten feet long with sand, and filtered a solution of carbonate of soda through it; and he found that the density of the liquid at its entrance was to that at its exit as 1·000 to 1·005. In this case, then, the sand had deprived the solution of part of its water, and had thereby increased the gravity of the liquid which percolated. Assuming, however, the accuracy of all these reported observations, it cannot be doubted that, *in a practical point of view*, the efficacy of sand, as a filtering medium, depends *on its mechanical, not on its chemical influence.*

Domestic Filters.—In coming now to notice small filters for domestic purposes, such a multitude of inventions and contrivances start up to view that, as Tomlinson says, how to choose and where to begin is difficult. There are certain classes of subjects, says the same authority, on which the genius of inventors seems to run riot. *Filters* form one of these, and *fire-escapes* another. In either class examples are as numerous as the attempts to solve the problem of perpetual motion, or to square the circle. Almost every kind of porous substance has been enlisted into the service of filters. The animal, vegetal, and the mineral kingdoms have each contributed. Charcoal—animal and vegetal—sponge, flannel, cotton, straw, hemp, saw-dust, wood shavings, branches and leaves, various kinds of porous stone, sand, pounded glass, zinc and iron filings, are a few only of the materials that have been recommended or used; and the methods of employing them are as various and as dissimilar as the substances themselves. The Editor considers the best filter for home use to be that of Forster of Liverpool, which he employs in his own house. The water percolates a fine porous stone, which removes all mechanical impurities, and imparts a freshness to the water, which is not the case when sponge, charcoal, and other substances are the filtering media. It is, as Tomlinson states, remarkable that very few filters were exhibited in the foreign department of the Great Exhibition. France sent three — two of stone and one of charcoal. An ingenious form of filter was exhibited by the Wenham Lake Ice Company, which consisted of a siphon, the extremity of the short limb of which is furnished with a box containing the filter, so that on inserting this into a cistern or cask holding water, and applying suction at the extremity of the longer limb, a stream of filtered water can be obtained, which may be arrested or drawn at will by shutting or opening the tap, as seen in the figure. In the laboratory, unsized paper is almost exclusively employed as a filtering medium. Other substances, such as flannel, tow, sand, pulverized glass, may occasionally be used.

An arrangement is also made for retaining the liquor in the filter at the same height, until the whole of the fluid to be percolated is expended. To insure this, the menstruum to be passed through is held in a flask inverted, the neck of which, as the reader will perceive by the wood-cut, dips into the liquor already contained in the funnel. As the liquor descends, and the neck of the flask becomes uncovered, a bubble or two of air enters; more liquor exudes, until the neck becomes again immersed, and all communication with the air is again cut off.

Vessels for Containing Water.—Lead and other metals are very useful to store water in. The Editor is very glad to find, however, that the clean, inexpensive, and beautiful material, slate, is coming into use for cisterns, instead of lead, which is a dangerous metal to have in contact with a liquid of such daily and universal consumption.

Distilled Water.—Certain technical and analytical purposes demand that the water employed by the operator or analyst be perfectly pure. To insure this, distillation is resorted to, by which operation the foreign matters held in suspension or solution are separated. Dr. Normandy remarks, that the distillation should be arrested when the salts begin to precipitate; for if the process were continued, part of these saline matters might suffer decomposition, and thus contaminate the distillate. The annexed table from Normandy shows the characteristics of pure water. It must not become turbid, or produce a precipitate with any of the subjoined reagents:—

Baryta water—If a precipitate or opaqueness appear, carbonic acid is present.
Chloride of barium—Shows sulphates.
Nitrate of silver—Indicates chlorides.
Oxalate of ammonia—Evidences lime salts.
Sulphide of hydrogen, solution made slightly acid—Antimony, arsenic, tin, copper, gold, platinum, mercury, silver, lead, bismuth, cadmium.
Sulphide of ammonium, solution alkalized by ammonia—Nickel, cobalt, manganese, iron, zinc, alumina, chromium.
Chloride of mercury, chloride of gold, sulphate of zinc—Prove organic matter.

Pure distilled water, evaporated on a piece of platinum foil, *should leave no residue.* As a drink it is insipid, and is not recommended except in some cases of calculi.

The following table, embracing the composition of some principal river and well waters, will prove interesting to the reader:—

GRAINS IN THE IMPERIAL GALLON.

	RIVER.								WELL.	
	Clyde, Glasgow. Penny.	Leven. Penny	Seine. Deville.	Rhine Deville.	Garonne Deville.	Loire. Deville	Rhone. Deville.	Doubs. Deville.	Arcneil Aqueduct, at Paris.	Dijon
Carbonate of lime,........	2·52	·50	11·609	9·511	4·524	3·374	5·334	13·397	12·958	16·133
Sulphate of lime,........	·26	·52	1·886	1·030	—	—	—	—	11·490	—
Chloride of calcium,......	—	—	—	—	—	—	—	—	—	—
Carbonate of magnesia,...	·72	—	·189	·350	·238	·427	3·430	·161	·575	·266
Sulphate of magnesia,....	—	—	trace	—	—	—	—	—	—	—
Chloride of magnesium,...	·40	·66	—	—	—	—	—	·035	1·163	—
Sulphate of soda,.........	1·94	·39	—	·945	·371	·238	·519	·357	·378	·189
Carbonate of soda,.......	—	—	—	—	·455	1·023	—	—	—	·147
Chloride of sodium,......	·54	·73	·862	·140	·224	·336	·119	·161	2·637	·224
Sulphate of potassa,......	1·94	·39	·350	—	·533	—	—	—	1·410	—
Nitrate of potassa,........	—	—	—	2·660	—	—	·280	·287	—	·189
Nitrate of soda,..........	—	—	·659	—	—	—	·315	·273	—	—
Nitrate of magnesia,......	—	—	·364	—	—	—	—	—	3·998	—
Phosphates—earthy,.....	·31	·18	—	—	—	—	·333	—	—	—
Alumina,...............	·28	·32	·035	·175	—	·498	—	·147	·371	·070
Oxide of iron,...........	trace	—	·175	·406	·217	·385	—	·210	—	—
Silicic acid,............	·28	·32	1·711	3·423	2·813	2·848	1·669	1·114	2·146	1·068
Organic matter,........	·89	·45	—	—	—	—	—	—	—	—
	7·86	3·75	17·840	16·247	9·585	9·437	9·082	16·142	37·126	18·283

Physiological Effects.—Water is an essential part of the blood and of the living tissues. It is from this liquid that the tissues derive their properties of extensibility and flexibility. It gives fluidity to the blood, and enables the transportation of organic particles from one part of the body to another to be effected. Lastly, it contributes to most of the transformations which occur within the body. Considered dietetically, aqueous drinks serve several important purposes in the animal economy: they repair the loss of the watery part of the blood, caused by evaporation and the action of the secreting and exhaling organs, and thereby assist the stomach in the act of digestion. If, however, they are swallowed in excessive quantity, they may impede digestion by diluting the gastric juice. It is not improbable that water acts as a real nutritive agent, that is, assists in the formation of the solid parts of the body. As an agent for the communication or abstraction of heat to or from the body, water has been before noticed. Furthermore, the influence of atmospheric humidity modifies the character of climates.

Water moderately warm, and which neither cools nor heats the body, acts locally as an emollient, softening and relaxing the various tissues to which it is applied. When swallowed, it allays thirst, becomes absorbed, mixes with and thereby attenuates the blood, and promotes exhalation and secretion, especially of the aqueous fluids. Administered in large quantities, it excites vomiting. The continued excessive employment of water has an enfeebling effect on the system, both by the relaxing influence on the alimentary canal, and by the excessive secretion which it gives rise to. Injected into the veins in moderate quantities, tepid water has no injurious effects; it quickens the pulse and respiration, and increases secretion and exhalation. Large quantities check absorption, and cause difficulty of breathing and an apoplectic condition. Thrown with force into the carotid artery, it kills by its mechanical effects on the brain.

Besides the dietical and thermotic purposes for which water is employed in medicine, it serves as a diluent, humectant, emollient, evacuant, and, in pharmacy, as a solvent. Water, or bland aqueous fluids, are employed in some cases of poisoning. They serve to dilute the acrid and irritant poisons, the intensity of the action of which on the stomach they lower. Moreover, the presence of aqueous fluids favors the expulsion of substances by vomiting. In preternatural dryness and rigidity of parts—for example, of mucous surfaces, the skin, wounds, and ulcers—water and mild aqueous fluids are useful moisteners and emollients. The copious use of water augments the quantity of fluid thrown out of the system by the cutaneous and pulmonic surfaces, and by the kidneys. If the object be to promote diaphoresis, external warmth should be conjoined with the internal use of diluents; whereas, when one wishes to excite the renal vessels, the skin should be kept cool. In inflammatory affections of the urinary passages, the free employment of aqueous fluids is advised, with the view of diluting the urine, and thereby of rendering it less acrid and irritating. What is called water-dressing may be regarded as a modified and improved form of poultice. It consists in the application of two or three layers of soft lint dipped in water, and applied to inflamed parts, wounds, and ulcers, the whole being covered with oil silk or Indian rubber, which should project beyond the margin of the lint to retain the moisture, and prevent evaporation. Dr. Macartney considers it to operate differently to a poultice; unlike the latter, he says, it prevents or diminishes the secretion of pus, checks the formation of exuberant granulations, and removes all pain. Moreover, the water is not liable to become sour like a poultice, and does not injure the sound part. Water is frequently employed in pharmacy for extracting the active principles of various medicinal agents.—*Pereira.*

MINERAL AND OTHER WATERS.—GLOVER justly remarks that few subjects connected with medicine are more interesting to the general reader than that of mineral waters. The circumstances attending their administration, the natural mode of their production, the scenery in which they are often placed, and the associations frequently surrounding them, combine to give them, as remedies, an interest exceeding that of ordinary medicinal agents. Hygiene and medicine, in the narrow acceptation of the terms, join hand in hand at the salubrious fountain. Spas have been exalted, and are still exalted by interested parties, as panacean cures for all diseases; others unworthily decried; source has been pitted against source, and pump against pump; and battles fought between biassed spa-doctors, which only tended to raise doubts in the opinions of thinking men.

To enter largely into the subject of natural and artificial mineral waters would be quite out of place in a book of this description, and it would be incompatible with the assigned limits to give more than a general insight into their nature, character, composition, and manufacture. The great *furor* for saline and other springs is daily abating; a very striking proof of this being evidenced at Cheltenham, to which thousands used to rush yearly to partake of its waters, whereas now it is almost entirely deserted. The same, no doubt, will soon be the case with other places, and artificial will, in many cases, supply the place of natural waters. Is not more due to the diet, change of scene and air, than to the virtues said to be possessed by certain springs? What miraculous cures are stated to have been produced by the water of Holywell, Flintshire, North Wales; and yet analysis reveals *nothing* particular in this spring to impart to it medicinal properties, as illustrated by the annexed tabulated results of Mr. JAMES BARRATT, pupil of the Editor—

Temperature,...... ...... 52°
Specific gravity, ...1·0015

	Grains. Per imperial gallon.
Carbonate of iron,........	traces
" lime,............	13·685
" magnesia,....................	2·688
" soda,............................	1·432
Chloride of calcium,....................	3·094
" potassium,.....	traces
" sodium,..........................	0·821
Silicic acid,................................	2·737
Sulphate of lime,........................	5·202
" magnesia,....................	traces
Total,............	29·659

Direct determination of fixed constituents, 30·450

Free carbonic acid, 10·338 grains, = 21·874 cubic inches.

This famous spring is the first in Great Britain; it never freezes, and scarcely varies in the quantity of water it emits, drought or wet weather, flinging out *twenty-one tons a minute.*

PEREIRA remarks—Mineral waters were known to mankind in the most remote periods of antiquity, and were employed medicinally both externally and internally. HOMER speaks of tepid and frigid springs. The Æsculapidæ, or followers of ÆSCULAPIUS, according to SPRENGEL, erected their temples in the vicinity of mineral and thermal waters. HIPPOCRATES mentions mineral waters, although he does not prescribe them when speaking of particular diseases. Their medicinal properties are spoken of by PLINY.

The principal source of saline waters is the rain, snow, hail, dew, percolating a certain portion of the soil, and dissolving various matters in their passage, so as to reappear on the surface at the bottom of declivities as spring-water; or when procured by sinking pits or wells—well-water. But springs are sometimes observed, continues PEREIRA, under circumstances which are inconsistent with the supposition of their atmospheric origin. The boiling springs, says GAIRDNER, which emerge on the verge of perpetual snows at an altitude of thirteen thousand feet above the level of the sea, as in the Himalayas, cannot be derived from the air.

Mineral waters, of course, procure their particular and distinctive properties or qualities from the strata through which they flow. Those of the primitive formation are almost all thermal, generally possessing a high temperature, while those of the older secondary formations are generally cooler. The hot or thermal waters are those possessing a degree of heat more or less raised above the mean of the latitude or elevation at which they are found, and the changes of which, if any, observe no regular periods coincident with the revolutions of the seasons. Three causes, says PEREIRA, have been assigned as the source of the temperature of mineral waters, namely, volcanic action, now in existence; volcanic, now extinguished, but the effects of which still remain; and a central cause of heat, which increases in descending from the surface to the interior of the earth. The *Geysers*, or boiling springs of Iceland, are evidently the result of volcanic action.

PEREIRA proceeds—The origin of the saline and other constituents of mineral waters is another interesting topic of inquiry connected with the natural history of mineral springs. As water, in its passage through the different strata of the globe, must come in contact with various substances which are soluble in it, one refers certain constituents of mineral waters to solution and lixiviation merely, as chloride of sodium, carbonates of lime and magnesia, oxides and bromides of sodium and magnesia, iron, silicic acid, *et cetera.* Chemical action must, in some cases, be the source of other constituents. Sulphide of hydrogen is most likely the result of the action of water on some metallic sulphide, especially iron pyrites; sulphurous or sulphuric acid from the oxidation and combustion of sulphur, free or combined. In acidulous or carbonated waters the carbonic acid probably arises from the decomposition of chalk either by heat or sulphuric acid. The disintegration of chlorides of sodium or ammonium would eliminate hydrochloric acid, while carbonate of soda, found so largely in the native lakes of Egypt, might, as BERTHOLLET supposes, be proved by the action of chloride of sodium or carbonate of lime; thus—

$$\underbrace{\mathrm{Na\,Cl}}_{\text{Chloride of sodium.}} + \underbrace{\mathrm{CaO\,CO_2}}_{\text{Carbonate of lime.}} = \underbrace{\mathrm{NaO\,CO_2}}_{\text{Carbonate of soda.}} + \underbrace{\mathrm{Ca\,Cl}}_{\text{Chloride of calcium.}}$$

Gairdner states that the different orifices of the Karlsbad Sprudel discharge annually about thirteen thousand tons of carbonate of soda and twenty thousand tons of sulphate of soda, in a crystallized state; and further adds, that a very simple calculation is sufficient to prove that the Donnersberg alone, the highest of the Bohemian Mittelgebirge, a cone of clinkstone two thousand five hundred feet in elevation, eviscerates soda sufficient to supply the Karlsbad waters for more than thirty thousand years.

The Editor agrees with Pereira that the best classification to adopt is that of grouping mineral waters into four classes, *videlicet*, chalybeate, sulphurous, acidulous, and saline.

Chalybeate or Ferruginous Waters.—These terms are applicable to those waters, the active principle of which is *iron* in considerable quantity. These waters possess a styptic taste, and when they contain the protoxide of the metal, yield, with ferrocyanide of potassium, a *white* or bluish-white precipitate; and if the sesquioxide be present, they give a *blue* precipitate with ferrocyanide of potassium, and become *red* with the alkaline sulphocyanide. The carbonated chalybeates are of two kinds, those containing the carbonate of iron, associated with much carbonic acid, which renders them acidulous and effervescent. The Pyrmont, Trinkquelle or drinking spring, Schwalbach Spa, and Pouhon, are of this nature.

The noneffervescent ones are Oddy's saline chalybeate at Harrowgate, the Islington Spa near London, and the waters of Tunbridge Wells. These are also sulphated chalybeates, but they are not of so much importance.

Sulphurous or Hepatic Waters.—The most celebrated of these waters are—in England, those of Harrowgate, the appended analyses by Dr. A. W. Hoffmann being given; Scotland—Moffat and Rothesay; of the Continent—Enghien, Barèges, Aix, near Geneva, Aix-la-Chapelle, and Baden. They have the disagreeable smell of rotten eggs, and give, with salts of lead, bismuth, copper, *et cetera*, black precipitates.

Subjoined are analyses by Dr. Hoffmann of several of the most important saline chalybeates at Harrowgate:—

GRAINS OF SALINE CONSTITUENTS IN THE GALLON OF WATER.

	Old sulphur well	Montpellier strong sulphur well.	Montpellier mild sulphur well.	Hospital strong sulphur spring.	Hospital mild sulphur spring.	Starbeck sulphur spa.
Temperature,	48·2°	46·4°	42·8°	41·9°	44·6°	48·2°
Specific gravity,	1·01113	1·01045	1·00314	1·00515	1·0026	1·0018
Ammonia,	trace	trace	trace	trace	trace	trace
Bromide of sodium,	trace	—	trace	trace	trace	trace
Carbonate of iron,	trace	trace	trace	1·060	trace	trace
" lime,	12·365	24·182	20·457	25·560	19·794	6·960
" magnesia,	—	—	3·251	5·797	—	—
" manganese,	trace	trace	trace	trace	trace	trace
" potassa,	—	—	—	—	—	12·207
" soda,	—	—	—	—	—	5·133
Chloride of calcium,	81·735	61·910	—	—	—	—
" magnesium,	55·693	54·667	17·140	11·595	0·336	—
" potassium,	64·701	5·750	3·975	10·751	24·970	—
" sodium,	866·180	803·093	232·413	369·014	220·630	121·798
Fluoride of calcium,	trace	trace	trace	trace	—	faint trace
Iodide of sodium,	trace	—	trace	trace	trace	trace
Organic matter,	trace	trace	trace	1·327	trace	1·740
Silica,	0·246	1·840	0·165	0·535	1·49	1·753
Sulphate of lime,	0·182	0·594	12·104	51·660	1·215	0·870
Sulphide of sodium,	15·479	14·414	3·398	7·155	0·301	1·711
Total,	1096·581	966·450	292·903	484·454	279·046	157·562

GASES DISSOLVED BY THE WATERS AND EXPELLED BY EBULLITION IN VACUO.

	Composition in one hundred volumes.					
	Old sulphur well.	Montpellier strong sulphur well.	Montpellier mild sulphur well.	Hospital strong sulphur spring.	Hospital mild sulphur spring.	Starbeck sulphur spa.
Carbonic acid,	61·06	70·62	62·50	31·79	44·07	49·78
Carbide of hydrogen,	16·17	2·71	3·99	0·52	22·80	27·71
Nitrogen,	8·08	24·21	33·51	65·88	25·31	22·51
Oxygen,	—	2·46	—	—	7·82	—
Sulphide of hydrogen,	14·69	—	—	1·81	—	trace
Total,	100·00	100·00	100·00	100·00	100·00	100·00

CUBIC INCHES OF THE GASES IN THE GALLON OF WATER.

	Old sulphur well.	Montpellier strong sulphur well.	Montpellier mild sulphur well.	Hospital strong sulphur spring.	Hospital mild sulphur spring.	Starbeck sulphur spa.
Carbonic acid,	22·03	14·01	14·28	9·54	10·20	9·26
Carbide of hydrogen,	5·84	0·53	0·90	0·15	5·28	5·15
Nitrogen,	2·91	4·82	7·67	19·78	5·87	4·21
Oxygen,	—	0·48	—	—	1·81	—
Sulphide of hydrogen,	5·31	—	—	0·54	—	trace
Total,	36·09	19·84	22·85	30·01	23·16	18 62

COMPOSITION OF THE GASES, IN ONE HUNDRED VOLUMES, RISING FROM THE WATER IN BUBBLES.

	Old sulphur well.	Hospital strong sulphur spring.
Carbonic acid,	3·28	0·09
Carbide of hydrogen,	40·00	—
Nitrogen,	56·72	99·91
Oxygen,	—	—
Sulphide of hydrogen,	trace	trace
Total,	100·00	100·00

The sulphide of hydrogen exists in the above waters, partly free and partly combined. Only a portion can be expelled by ebullition. The amount of the sulphide of hydrogen in the waters varies, which may be partly due to influences affecting the strata through which the waters ascend; to a great extent, however, they must be ascribed to the action of the air.

The general operation of these waters, says PEREIRA, is stimulant. They are adapted for chronic complaints, and are supposed to possess a specific power over the cutaneous and uterine systems, and are said to be beneficial in chronic rheumatism and gout. As previously remarked, would not an iron salt, judiciously administered, act just as well in the above-mentioned diseases?

ACIDULOUS OR CARBONATED WATERS.—The name here implies waters charged with carbonic acid. Most waters contain a few cubic inches of carbonic acid in the gallon, but the acidulous will eviscerate from thirty to two hundred cubic inches. It is stated by ALIBERT that the waters of Saint Nectaire hold four hundred cubic inches in one hundred of the water.

Carbonate or bicarbonate is contained in waters of this kind, and, when this is the case they are called *acidulo-alkaline*. The Selters, Altwasser, Saltzsbrunn, Reinerz, and Pyrmont acidulous waters are of this description. Protocarbonate of iron is sometimes present in them, classifying them under *acidulous carbonated chalybeates*. The spring at Ilkeston, near Nottingham, is the only water of the above class in Great Britain.

Acidulous waters are cooling, refreshing, and exhilirating, and oftentimes relieve nausea. The acidulo-alkaline waters are useful in the lithic acid diathesis, in gout and rheumatism, *et cetera.*

SALINE WATERS, according to PEREIRA, may be divided into five kinds:—

Purging Saline Waters.—Sulphates of soda or magnesia are the active ingredients of these waters: some owe their efficacy to sulphate of magnesia, others to sulphate of soda.

Bitter Purging Waters, Bitter Waters, Bitter-Salt Waters.—Sulphate of magnesia predominates in these waters. Epsom and Scarborough in England, and Seidlitz, Saidchütz, and Püllna on the Continent, are of this kind. Some thermal springs, as those of Acqua del Pozzeto, near Pisa, contain sulphate of magnesia.

Glauber Salt Waters. — Some writers give this name to those waters holding sulphate of soda in solution. Some of these are warm, and on this account are called the *warm alkaline glauber salt waters.* To this division belong the famous springs of Carlsbad, now so much resorted to for good—or evil! Further on analyses are given of the Carlsbad water, and of several others of the leading and well-known Continental springs. Some of this class of waters are devoid of alkaline properties, but contain, besides sulphate of soda, various earthy and alkaline salts. They are the *earthy glauber salt waters.* To this division belong the deserted springs of Cheltenham, and those of Leamington and Spital.

In large doses the waters of this kind are mild cathartics. PEREIRA says they are useful in diseased liver, dropsical diseases, *et cetera.*

Salt or Brine Waters.—The characteristic ingredient of these springs is chloride of sodium. Iodine or bromine, or both, have been found in some of them, and these most likely add to their medicinal effects. The small quantity of iodine recently found in the water of St. Ann's Well at Great Malvern, Worcestershire, by the Editor, is doubtless the active ingredient in that water.

The Kreuznach and Salzhausen springs in Germany are among the brine springs, and in England the principal ones are at Middlewich and Nantwich in Cheshire, Shirleywich in Staffordshire, and Droitwich in Worcestershire.

Taken in large quantities, saline or brine springs are emetic and purgative. They have been principally celebrated in glandular swellings. The water of Baden Baden contains a large quantity of chloride of sodium.

Analysis of the water of Baden Baden by the Editor:—

	Imperial gallon. Grains.
Alumina,	trace
Carbonate of iron,	1·356
" lime,	14·184
Chloride of calcium,	11·040
" potassium,	13·720
" sodium,	132·644
Organic matter,	trace
Phosphate of lime,	trace
Silicic acid,	2·947
Sulphate of magnesia,	5·236
	181·127

Specific gravity	1·00284
Carbonic acid	4 5 cubic inches.
Sulphide of hydrogen	trace.

Calcareous Waters.—These saline mineral waters, the leading constituent of which is either the sulphate or carbonate of lime, belong to this order.

The Buxton, Bath, and Bristol thermal waters, come under the same category. Annexed is an analysis of the Buxton water just completed by the Editor; it differs materially from the one made by his friend PLAYFAIR some time ago, except in the amount of gases:—

	Grains in the imperial gallon.
Carbonate of lime,	8·541
Carbonate of magnesia,	3·741
Carbonate of protoxide of iron,	0·082
Sulphate of lime,	0·330
Chloride of calcium,	1·227
Chloride of magnesium,	0·463
Chloride of sodium,	2·405
Chloride of potassium,	0·260
Silica,	1·044
Nitric acid,	trace
Organic matter,	0·341
Fluoride of calcium,	trace
Phosphate of lime,	
Total per gallon,	18·434

Free carbonic acid, 3·5 cubic inches.
Nitrogen, 504 "

Calcareous waters are stimulant, alterative, and constipatory. Externally they are said to be beneficial in the cure of rheumatism, gout, chlorosis, chronic skin diseases, *et cetera.*

The quantity of nitrogen gas accompanying this water has been previously alluded to. Dr. Robertson, in treating of the physical characters of the Buxton waters, ascribes their brilliancy when drawn to the quantity of gas *held in solution.* Of course, this must be fallacious, for very little gas is *held in solution* or *dissolved.* As Glover remarks, what occurs in the baths, where a quantity of the nitrogen has been forced along by the current of water, three hundred gallons per minute, furnishes no indication of the amount of *gas in solution.* The great use of the Buxton water is, of course, externally, but upon what its effects mainly depend *still remains unexplained.*

Mr. J. Armitage Pearson, the eminent consulting surgeon of Buxton, has informed the Editor that he does not look upon the *nitrogen* in any water to be an effective element; and although one sees the gas constantly gurgling forth in strong streams, still Mr. Pearson agrees with the Editor, that being an *insoluble* gas, it is not absorbed into the system; and even *supposing that it could be absorbed,* it could not exert any beneficial result. All water is a diuretic, more or less. Mr. Pearson places very little value on the Buxton waters *per se;* but administered with a certain and most valuable medicine—an alkaloid—which he has prescribed, he has effected several wonderful cures. The lime salts in the water no doubt exert a beneficial influence.

To divert the reader's attention a little, the following anecdote with regard to how waters of one kind or another become celebrated, is given by the writer of *Bubbles from the Brunnens of Nassau,* with regard to the discovery of the far-famed waters of Sclangenbad. It is characteristic of the supposed origin of many similar watering-places, and as such it may amuse, if it does not much edify, the reader:—In the history of the little Duchy of Nassau, says that graceful writer, the discovery of the spring forms a story full of innocence and simplicity. Once upon a time, there was a heifer with which everything in nature seemed to disagree. The more she ate, the thinner she got. The more her mother licked it, the thicker and more staring was her coat. Not a fly in the forest would bite her. Never was she seen to chew the cud; but, hide-bound and melancholy, her hips seemed to be actually protruding through her skin. What was the matter with her no one knew; what could cure her, no one could divine; in short, neglected by her master and her species, she was, as the faculty would term it, *given over.* In a few weeks, however, she suddenly reappeared among the herd with ribs covered with fat, eyes like a deer, skin as sleek as a mole, breath smelling sweetly of milk, saliva hanging in ringlets from her jaw. Every day seemed to re-establish her health, and the phenomenon was so striking, that the herdsman, having watched her, discovered that regularly every morning she wound her way in secret into the forest, until she reached an unknown spring of water, from which, having refreshed herself, she quietly returned into the valley. A young Nassau lady showed symptoms similar to those of the heifer, and the herdsman recommended the water, which cured her!

Glover says justly in his very readable work on mineral waters, that there is a certain mystery connected with the origin and mode of operation of some of them, which no doubt with many is attractive, just as in the extraordinary doctrines of Hahnemann and others. Many of these waters, and especially the thermal ones—Buxton, *et cetera*—produce effects in general estimation far beyond what can be accounted for, either by their chemical composition and the power of their *known* ingredients, or by their temperature as shown by the thermometer, in comparison with those of ordinary water baths.

Alkaline Waters.—Carbonate and bicarbonate of soda are the characteristic ingredients in such mineral waters. The thermal springs of Teplitz and Ems come under this class, also the Vichy waters, which have long been noted for the cure of stone and gravel; but of late years they have been the subject of discussion among French physicians as to their efficacy in these disorders.

Among the mineral waters in this country which contain carbonate of soda are those of Ilkeston in Derbyshire, near Nottingham, and Malvern in Worcestershire, an analysis of the latter being appended. These waters have only recently been minutely analyzed in the Editor's laboratory:—

	St Ann's Well, Great Malvern. Editor.	Holy Well, Malvern Wells Barratt.
	In the imperial gallon.	
Alumina,	—	traces
Carbonate of iron,	0·0331	0·22470
" lime,	0·4310	1·02480
" magnesia,	0·4111	1·48400
" soda,	0·2844	0·93310
Chloride of magnesium,	0·1448	—
" sodium,	0·8768	0·94570
Iodide of potassium,	0·00021	—
" sodium,	—	0·00029
Silicic acid,	0·2057	0·19250
Sulphate of lime,	1·1521	1·65690
" soda,	0·4382	0·09360
Organic matter,	—	traces
	3·9772	6·55859
Specific gravity	1·0013	1·0012
Carbonic acid in cubic inches	1·382	6·722
Temperature	48°	46°

The above waters issue from the rock at the rate of about three gallons a minute, and they have been renowned as highly advantageous as an external application to indurated scrofulous tumors, ulcers, and many eruptive diseases, owing to the trace of iodine, as well as efficacious and beneficial when taken internally, for acidity, dyspepsia, *et cetera*—if so, why not take the active ingredient *per se at home?*

Dr. **BOOKER** thus apostrophizes the Holy Well—

> Ever could I stray
> Beside thy stream thou purest spring that flows;
> Climb each bold eminence, and daily find
> Some object new for wonder—ever gaze
> On the wide scene around me, and regale,
> When thirst demands, or pleasing taste invites,
> At thy clear rill that sparkles at my foot,
> And think it luxury.

Chemically it is not *the purest spring that flows*, that of St. Ann being much *purer*. Poetically, however, it may be.

Silicious Waters.—Most mineral waters contain traces of silicic acid, but some hold it in such quantity that the term *silicious* is applied to them. In the boiling springs of Geyser and Reikum in Iceland it amounts to nearly the half of the solid constituents. The action of such water—of course the silica is united to an alkali—will be similar to those of the soda or potassa waters. Annexed are analyses of several of the most important mineral waters on the Continent:—

	Sprudel Carlsbad. Temp. 165° sp. gr. 1·00487.	Ems. Kesselbrunnen. Temp. 115° sp. gr. 1·0034.	Selters. Temp. 60 5° sp gr. 1 0036.	Gastein. Temp. 95° sp. gr.	Teplitz, Hauptquelle. Temp. 1 9° sp. gr 1·00065.	Wildbad. Temp. 90 5° sp gr.	Kissingen. Temp. 52° sp. gr.	Kreuznach Karlshaller-brunnen. Temp. 61·5° sp. gr. 1·006.	Pyrmont Trinkquelle Temp. 57° sp. gr.
Carbonate of baryta,......	—	0·03	—	—	—	—	—	—	—
" iron,.........	0·27	0·26	1·54	0·22	0·37	0·20	6·80	3·64	4·90
" lithia,........	—	—	—	—	1·82	—	—	—	—
" lime,........	23·70	11·40	18·67	3·97	3·25	3·40	35·50	6·13	59·88
" manganese,..	0·06	0·03	—	trace	0·80	—	trace	6·54	0·48
" magnesia,...	13·69	7·88	15·95	0·35	0·53	0·70	25·00	4·73	3·23
" soda,........	96·95	107·50	58·55	6·90	26·84	5·30	8·20	—	—
" strontia,....	0 07	0·10	trace	trace	0·19	—	trace	—	—
Sulphate of lime,........	—	—	—	—	—	—	25·00	—	72·21
" lithia,.........	—	—	—	—	—	—	—	—	0·09
" magnesia,....	—	—	—	—	—	—	—	—	26·97
" potassa,.......	—	5·40	—	0·55	4·34	0·20	—	—	0·42
" soda,..........	198·69	—	2·48	14·95	—	4·00	20·00	—	21·45
" strontia,......	—	—	—	—	—	—	—	—	0·20
Phosphate of alumina,.....	0·02	0·018	—	—	0·22	—	—	—	0·14
" lime,........	0·01	—	—	trace	—	—	—	—	—
" soda,........	—	—	2·81	—	trace	—	1·70	—	—
Chloride of ammonium,...	—	—	—	—	—	—	0·50	—	—
" calcium,.....	—	—	—	—	—	—	—	25·61	—
" lithium,.....	—	—	—	—	—	—	—	0·56	—
" magnesium,..	—	—	—	—	—	—	68·50	6·79	11 26
" potassium,...	—	0·45	3·58	—	1·04	—	9·10	4·07	—
" sodium,......	79·75	76·34	162·85	3·40	4·33	18·20	620·50	596·65	—
Iodide of magnesium,....	—	—	—	—	—	—	trace	—	—
" sodium,.........	—	—	—	—	0·56	—	—	0·44	—
Bromide of magnesium,...	—	—	—	—	—	—	7·00	66·02	—
Fluoride of calcium,......	0·24	0·019	—	—	—	—	—	—	—
" sodium,......	—	—	—	—	1·30	—	—	—	—
Alumina,.............	—	—	—	0·50	—	—	1·80	4·32	—
Silicic acid,.............	5·77	4·14	2·89	2·02	3·12	3·90	22·50	0·31	4·96
Glairine,................	—	—	—	trace	0·90	—	5·30	14·72	—
	419·22	213·567	269·32	25·96	49·61	35·90	857·40	760·53	206·19

SEA WATER—*Aqua Marina.*—The waters of the ocean and inland seas are comprised under this head. It is rather a remarkable fact that the Dead Sea differs greatly in its constitution from sea-water, and might, as stated by **PEREIRA**, to whose excellent work the Editor is indebted for most of the preceding valuable information, be ranked amongst mineral waters.

According to the analysis of **MARCET**, the water of the Dead Sea contains 24·6 per cent. of fixed matter, and possesses an extraordinary density, 1·211—

	Centesimally represented.
Chloride of sodium,...............	10·360
" calcium,...............	3·920
" magnesium,............	10·246
Sulphate of lime,.................	0·054
Water,............................	75·420
	100·000

The amount of saline matters varies considerably in different seas, as instanced by the following results from **PFAFF**. The solid constituents are in ten thousand parts of the water of each:—

Mediterranean..................................		410
English channel................................		380
German ocean	At the Island of Föhr	340
	" " of Noderney.....	342
	In the Frith of Forth..........	312
	At Ritzebüttel................	312
Baltic Sea.	At Apenrade in Sleswick.......	216
	At Kiel in Holstein	200
	At Doberan in Mecklenberg....	168
	At Travenmünde..............	167
	At Zoppot in Mecklenberg	76
	At Carlsham................	66

To assume that the average quantity of solid matter is three and a half per cent., and the density about 1·0274 will be very near the mark.

Annexed are the analyses of **SCHWEITZER** and **LAURENS**, of two samples of sea-water:—

	English Channel. Schweitzer.	Mediterranean. Laurens
Chloride of sodium	27·05948	27·22
Chloride of potassium	0·76552	0·01
Chloride of magnesium	3·66658	6·14
Bromide of magnesium	0·02919	—
Sulphate of magnesia	2·29578	7·02
Sulphate of lime	1·40662	0·15
Carbonate of lime	0·03301	0.20
Carbonate of magnesia	—	
Water	964·74372	959·26
	1000·00000	1000·00

Schweitzer also detected iodine and ammonia, and Balard found iodine in the Mediterranean; and no doubt it contains bromine and other constituents. In fact Malaguti detected *silver* in sea-water.

To render such water fit for drinking, it is evident that the greater part of these saline constituents must be removed; and, as Tomlinson remarks, it has long been a desideratum to enable ships' crews to employ sea-water for different culinary purposes, with the view of removing the necessity of carrying large supplies of fresh water. Almost innumerable are the contrivances invented to meet this end, and, according to the above-cited authority, the most effective is Grant's, by which the cooking of victuals and the purifying of water are carried on synchronously. The apparatus is called *the distilling and cooking galley.* The galley contains the fires and vessels necessary for cooking. During the time when the fires are ignited, a portion of the heat is applied to the external part of vessels containing sea-water; the water boils, and steam distils over, leaving, of course, the salts in the still. The steam condenses in a worm, and is nearly pure water, which, of course, is vapid; but the taste may be improved by access to open air and agitation. Where steam-power is used, Grant's apparatus affords a ready and effective means of separating fresh-water from salt. Pereira says that Clark's patent improved pyrohydropneumatic apparatus for easily converting sea-water into fresh is a convenient form of still adapted for sea service. Congelation separates fresh from sea-water. In freezing the pure water only congeals, not the saline ingredients; hence the ice of the polar seas yields fresh water.

Physiological Effects and Uses.—Sea-water taken into the stomach excites thirst, nauseates, and in large doses occasions vomiting and purging. The repeated use of it in moderate doses has been found of service on account of its alterative and resolvent operation in scrofulous affections, especially glandular enlargements and mesenteric diseases. Its topical action is more stimulant than ordinary water. It is used as an embrocation in chronic diseases of the joints. Baths of it are not so exhausting as those of common water. It is a popular opinion, perhaps well founded, that patients are less likely to catch cold after the use of salt than of fresh water.—*Pereira.*

Artificial and Aerated Waters.—About forty years ago, when the fabrication of mineral and spa waters commenced, a very violent opposition arose with regard to them, especially from the members of the faculty. They were said to be devoid of all the good qualities of the natural ones—to be minus a certain *conditio sine qua non*, in the shape of a *spiritus rectus*, or vital force, which imparted the medicinal qualities. The Editor has lived to see such statements reversed. Chemistry, the great revealer of hidden treasures, has demonstrated to a certainty what the constituents of the natural waters are; and thus one is now enabled to produce artificial waters quite equal, if not superior to the natural ones. At the Brighton pump-room many artificial waters are prepared imitative of those of Carlsbad, Pyrmont, Vichy, Kreuznach, Ems, Seltzer, and many others, too numerous to detail. Messrs. Ellis of Ruthin prepare a beautiful imitation of the Seltzer water which, on being analysed by the Editor, yielded exactly the same constituents as the far-famed Bohemian spring. The artificial is certainly more palatable than the natural water, owing probably to the freshness of the carbonic acid infused into it by the admirable apparatus of Tyler, which will be explained further on. To dwell particularly on artificial waters would be tedious and uninteresting to the reader; it is sufficient to state that in their manufacture the salts, in the same proportion as contained in the natural spring, are dissolved in as pure a water as possible, and are then more or less charged with carbonic acid or other gases.

It was Priestley who, in 1772, proposed to impregnate water direct with carbonic acid, and in 1774 prescriptions for the artificial production of Selters and Pyrmont waters, founded on an accurate analysis of the same, were published by Bergmann.

Some years ago Liebig analysed the Friedrichshaller water, and it is now prepared in large quantities exactly with the salts, *et cetera*, and in the same proportion as given in his results; and if one may judge by the success the imitation has met with, the artificial has almost entirely supplanted the natural beverage. The Editor may here remark, that it is to a certain extent immaterial whether one dissolves carbonate of magnesia, carbonate of lime, sulphate of lime, chloride of sodium, sulphate of soda, *et cetera*, or, on the other hand, chloride of magnesium, chloride of calcium, carbonate of soda, and sulphate of soda, if care be taken that the proportion of the respective bases and acids are strictly in accordance with the figures given by analysis; since they will, in all probability, combine in the same manner as they are associated in the natural spring. The rapid increase and spread of the manufacture of artificial waters, is the best proof that physicians find the medical and therapeutic effects of them are *identical* with those of the natural ones, whilst their *identity* in a physical and chemical point of view can hardly be questioned.

Now that the chemist is able to distinguish the ingredients actually efficacious in a water, a much more active mixture than the native spring can be prepared. To show the extent to which the manufacture of aerated waters has advanced, Messrs. Ellis and Son, the celebrated manufacturers of soda and other carbonated beverages, inform the Editor, that at Ruthin alone, North Wales, they send out yearly *many thousand gross of effervescing beverages.* So that with other factories at London, Malvern, Liverpool, Manchester, Glasgow, *et cetera*, the trade has within the last few years become an enormous one.

Soda-Water.—This is certainly the principal aerated water manufactured. How many thousands or millions of bottles of it are drunk annually either alone or mixed with sirups, wines, or spirits? The materials for soda water are carbonate of soda and tartaric acid.

It is a well-known fact that a large portion of the SODA water in general use is simply carbonated water, without the alkali, and as such, is a safe and agreeable beverage; but the physician, or the invalid, or any one who seeks therapeutic and corrective influences of the water, will be greatly disappointed in the use of these fluids, as they are inert, and for such purposes worse than useless. It is difficult to find a person who is not subject to occasional annoyance from acidity. To such an individual a glass of soda-water has been found to impart immediate relief. The carbonic acid appears to produce a peculiar sedative action upon the irritated mucous lining of the stomach, and the alkali neutralizes the excess of acid, and restores the organ to a condition of comfort which few but those who have suffered from the annoyance of heartburn can appreciate. Dr. BENCE JONES, in a treatise upon gout, strongly recommends the use of soda or potassa waters, but laments that the waters so-called in commerce are not alkaline at all; and numerous physicians of eminence have expressed the same complaint.

Some time ago the Editor was greatly pleased in inspecting the admirably conducted establishment of ELLIS at Ruthin, North Wales. Everything was so nice and clean; and, as for the water employed from a deep and splendid well upon the premises, it might be said to be absolutely pure; and it is on this account that he considers the soda, potassa, and other beverages prepared in these works superior to any other in the market. Messrs. SCHWEPPE and others, no doubt, manufacture equally well; but they do not start with *as pure a fluid.* The quantity of soda or potassa in each bottle at Ruthin is twenty-five grains of the bicarbonate of either alkali; and the carbonic acid is equal to about two hundred and fifty or sixty cubic inches, showing how well the gas is compressed. The water from the well only holds *two grains* of solid matter in solution, and *has not a trace of organic matter;* hence it is not liable to alterate or decompose, if kept for any length of time. The apparatus will now be described; and for the following, the Editor is again, as in several instances, indebted to TOMLINSON'S excellent Cyclopedia.

An elegant little apparatus has been brought into use within the last few years, patented by M. MATHIEU, as an improvement upon an earlier invention. It is calculated for the preparation of aerated beverages in private houses rather than for sale, since it can yield but a small quantity at a time. There are two oval glass vessels—the larger one placed vertically over the smaller. There is a passage of communication from the one to the other, and in this passage there is a tap for drawing off the aerated liquid. The upper or larger glass is filled with water by removing the cover: and the lower or smaller glass is supplied with the powders. These powders are, as in other cases, of different kinds, according to the sort of beverage to be produced. A small pipe descends from nearly the top of the upper to nearly the bottom of the lower vessel; a little water descends through this pipe, mixes with the powder, and produces gases; and these gases ascend to the water in the upper vessel. Of course, such gases only as are soluble in water are generated. The gas chiefly used is carbonic acid, of which water will absorb its own bulk, and by pressure can be made to take up another volume. As the gas accumulates in the upper vessel, the pressure increases, and the water is thus enabled to take up its additional supply. The two vessels are generally surrounded with a netting of wire or cane for security. In the simpler forms of the apparatus, nothing further presents itself; but in M. MATHIEU'S improvement there is a refrigerating contrivance. The upper vessel is surrounded by an external shell and sheath, so as to leave an intervening space; and into this may be introduced either ice, or cold water, or freezing mixture.

GAILLARD and DUBOIS' gazogene, or aerated water apparatus, is a much more complicated contrivance. It contains three distinct chambers or vessels—one for the water to be aerated, one for the effervescing powders, and one to contain a small quantity of water which is to act upon the powders. It is necessary to separate all three vessels when the apparatus is to be prepared for use; and this is one cause of its complexity. When all three have been properly supplied, the finger is pressed upon a stud or button at its top. This pressure opens a valve which allows the water in the small upper vessel to descend into the one containing the powders. The gas, thus generated, can only escape from the powder-vessel by descending a small tube which dips into the larger one; and the water with which this larger vessel is nearly filled becomes impregnated with the gas. A second finger-stud governs the valve of a small pipe, which enables the aerated water to flow from the apparatus, which is elegant in construction, but has not the elegance of simplicity.

Mr. MASTER'S aerating machine is similar in principle to MATHIEU'S, though differing in details. The powders are placed in the lower part, and the water in the upper; a little water descends to the powders, and the generating gas ascends. A stud, acted upon by the thumb, draws off the beverage when required.

Messrs. TYLER, HAYWARD and Company's patent double soda-water machine is adapted for bottles, and can make three hundred dozen *per diem.* There are two distinct machines in one frame, which can be worked together or separately. It consists of a condenser divided into two by a partition inside. Each half has an agitator, worked by a wheel. There are two condensing pumps, with regulating taps for admitting aerated water. The pumps are worked by a beam, The beam, by its reciprocating motion, causes the plungers beneath the pumps to ascend and descend in their barrels, forcing at each successive stroke the gas and water together into the condenser. About ten minutes are required to get the charge up, and the bottling then goes on uninterruptedly.

Messrs. TYLER and Son have invented single and double soda-water machines of ingenious construction. Mr. W. COX of Manchester has patented an apparatus in which the impregnating gas may be sustained at a pressure sufficient to cause its absorption by the water without the aid of force-pumps. **BAKEWELL'S** apparatus is another contrivance, applicable to the preparation not only of cooling drinks, but of effervescing draughts also, whether tonic, aperient, diuretic, antacid, or pectic. In short, every aerating apparatus may be said to comprise these two parts—one to produce a gas, and one to mix it with plain water, or water containing carbonates of soda, potassa, magnesia, *et cetera*, or orangeade, lemonade, gingerade, and the like.

ANALYSIS OF WATERS.—*Method of Testing for and Determining Nitrous and Nitric Acids.*—Almost all river waters, and especially the shallow well waters of towns, contain variable quantities of nitrous and nitric acids generally in combination with lime, as nitrite and nitrate of that base. Their constituents have hitherto been generally overlooked by analysts, but on their presence and quantity the chemist may form a more correct idea as to the contamination of the water by organic matter than by any other means. The Editor, therefore, attaches the greatest importance to the determination of these constituents, especially when the water is selected for domestic use.

It has been previously stated that ammonia is one of the principal products of the decomposition of animal matter. This ammonia very speedily becomes oxidized and converted into nitrous acid—NO_3—which, by longer exposure, is further oxidised into nitric acid —NO_5. The above-mentioned acids depend for their origin on the presence of organic matter capable of yielding ammonia, and *the solvent action* of waters upon lead, is almost entirely due to these acids.

Method of Determining the Hardness of Water.—The so-called *hardness* of a water is dependent, as already stated, upon the presence of a certain proportion of the salts of lime and magnesia, which possess the property of decomposing an equivalent quantity of soap, and rendering it useless as a detergent. These salts are bicarbonates of lime and magnesia, and the sulphates of the same basis. The former impart to water its *temporary*, and the latter its *permanent* hardness. The two bicarbonates are decomposed by boiling; the insoluble monocarbonates being deposited, and, mixed with small quantities of the other mineral constituents, form the incrustations which are frequently observed on kettles and boilers in which hard water is employed. In order to determine the temporary and permanent hardness of water, the following method is adopted:—

Into a six ounce stoppered bottle put one thousand grains of water; agitate briskly, and suck out the air by means of a piece of glass tube. This is necessary in order to remove the free carbonic acid, which might interfere with the soap test. Fill the graduated burette with soap test solution, add one measure, and agitate briskly. If no lather is produced, add more, and shake again. Continue adding the soap-test till a permanent lather is produced. Even in moderately hard water a white opalescence appears immediately on adding a few drops of the test, and a white curdy mass will be seen to collect on the surface. Pure soap, such as is used in making the test solution, is a stearate or palmitate of soda, which is readily soluble in pure water; but when it is added to a water containing salts of lime and magnesia, the soluble soda-soap is decomposed, and an insoluble soap of lime and magnesia produced. The decomposition is represented in the following equation:—

$$\underbrace{\text{NaO, St.}}_{\substack{\text{Stearate of soda} \\ \text{(soap.)}}} + \underbrace{\text{CaO, SO}_3.}_{\text{Sulphate of lime.}} \doteq \underbrace{\text{CaO, St.}}_{\text{Stearate of lime.}} + \underbrace{\text{NaO, SO}_3.}_{\text{Sulphate of soda}}$$

A similar decomposition takes place with soluble salts of magnesia, and hence, when hard waters are used for washing, not a particle of soap will act as a detergent until the whole of the lime and magnesia is removed.

In accurate analysis it is important to make a double determination of the hardness—one before the water is boiled, and another after a portion has been boiled for about six hours. The degree of hardness after boiling represents the hardness due to sulphates and chlorides of the alkaline earth metals, while the difference between the hardness obtained after and before ebullition indicates that which is due to the carbonates of those metals. For example, if a water has a hardness of fourteen degrees before boiling, and of four degrees after, the water is then said to have a temporary hardness of ten degrees, and a permanent hardness of four degrees.

That the determination of the hardness of water is important cannot be denied, since it furnishes a certain guide to the proper association of the acids and bases when one comes to arrange the results of a complete analysis. But until chemists are agreed upon the character of a type-water, its true value cannot be properly appreciated.

Determination of the free Carbonic Acid in Water—Water which has been allowed to stand for some hours in an open vessel becomes insipid and mawkish to the taste, or in popular language, it is flat. This is owing to the escape of carbonic acid, which occurs in many spring and well waters. Hence, in giving a correct opinion of the value of a water for dietetic purposes, it is sometimes necessary to determine the number of cubic inches of free carbonic acid in a given measure of the water. This is an operation which ought to be performed at the source, and is best done in the following manner:—A well-stoppered glass bottle holding a gallon is required for the purpose. Put into it two fluid ounces of strong ammonia, and two fluid ounces of a saturated solution of chloride of calcium. If both materials are pure, the mixture will remain perfectly bright. After observing that no milkiness is produced, depress the bottle into the stream or well, and fill it gradually, taking great care not to dip the neck entirely beneath the surface, but only partially, so as to allow space for the air to pass out, while the water is flowing in. This precaution is essentially necessary, since, if the water were to be agitated by the air escaping from the bottle, much of the free carbonic acid would be expelled by the agitation so occasioned, and hence erroneous results would be obtained.

After carefully filling the bottle with the water, it is to be stoppered and left for three or four days. After that time, the whole of the carbonic acid will have been precipitated in the form of carbonate of lime. This is to be filtered off, dried, and weighed. From the total weight of the precipitate is calculated the quantity of carbonic acid according to the following formula—

$$50 : 22 :: \text{the weight of carbonate of lime} : x$$

The value of x will give the quantity of carbonic acid contained in the water.

Some, however, of this carbonic acid is in combination with lime and magnesia, and it is therefore necessary to determine the quantity, in order to ascertain how much exists in a free state. This requires a separate operation. A gallon of the water is introduced into a large glass flask, and boiled for six hours. The diminution in bulk occasioned by evaporation is made up with pure distilled water. The precipitate produced by boiling is collected on a filter, and the portion adhering to the bottom of the flask is dissolved by a little dilute hydrochloric acid. The precipitate on the filter is dissolved, and the two solutions mixed together. The solution will contain traces of silica, iron, alumina, and phosphate, which may be disregarded; its chief components are carbonate of lime and carbonate of magnesia, which being separately determined, their weight is to be deducted from the weight of the precipitate obtained from the bottle in which the ammonia and chloride of calcium had been used. From the difference may be calculated the quantity of carbonic acid per gallon. One grain by weight measures as nearly as possible two cubic inches. Therefore, if the difference in the weights of the two precipitates amount to a weight of carbonate of lime containing twenty grains of carbonic acid, the water will be proved to contain forty cubic inches of that gas in a free state per gallon.

Determination of the Alkalinity of Water.—By the alkalinity of water is understood the quantity of potassa or soda which may be present in combination with carbonic acid. For ordinary drinking purposes it is quite unnecessary to perform this operation, but when water is used for brewing, dyeing, and starch-making, the presence of the alkaline carbonates is a matter of great consequence. The following method, though by no means perfect, is generally adopted. Two gallons of the water are evaporated in a large platinum dish down to about four fluid ounces. This is filtered from the deposit, colored with tincture of litmus, and then neutralized by a standard solution of sulphuric acid, containing in a hundred cubic centimeters as much acid as will neutralize one grain of alkaline carbonate.

Determination of Chlorine.—Half a gallon of water is evaporated to about four fluid ounces. Dilute nitric acid is then added to dissolve the precipitated carbonates. The whole is transferred to a beaker glass and filterer, the filter being thoroughly washed. To the solution is now poured in a slight excess of nitrate of silver, which throws down all the chlorine as chloride of the metal. The menstruum is now boiled, filtered, and the precipitate well washed with hot distilled water, then dried at 212°, ignited in a porcelain crucible, and weighed—143·5 of chloride of silver contain 35·5 of chlorine.

In determining the chloride of silver, the filter containing it should be completely exsiccated, then ignited very gently in the porcelain crucible; as soon as it ceases to burn, the carbonaceous residue of the filter should be slightly moistened with concentrated nitric acid, and again burned. By repeating this process several times, until all the carbon of the filter is destroyed, any loss of chloride of silver will be avoided; but before weighing, it is well to moisten the residue with hydrochloric acid, and ignite, in order to convert any reduced metal into chloride.

Determination of Sulphuric Acid.—Half a gallon of the water is, as in the preceding instance, evaporated to three or four ounces, and acidified chloride of barium is then to be added, and the whole boiled, and left for twelve or more hours in repose, then filtered, and the sulphate of baryta washed thoroughly and dried. 116·5 of sulphate of baryta represents 40 of sulphuric acid.

Directions for determining in Water the Non-volatile Organic Matter—Silica, Iron, Alumina and Phosphates; Lime and Magnesia.—Evaporate slowly half a gallon of water to about a pint, over a gas flame; then transfer the dish to a sand-bath, and continue the evaporation till the bulk is reduced to about *two* fluid ounces. Now accurately weigh a clean platinum dish. Scrape the deposit carefully from the bottom of the porcelain basin, and rub off that which cannot be removed by the platinum knife with the middle finger; rinse the whole into the platinum dish, and then evaporate to dryness on a water-bath. Be careful to observe that every particle of the deposit is removed from the porcelain vessel. When the residue is dry place the dish in an air-bath, and heat it for half an hour or an hour at a temperature of 260°.

The object of heating the residue to this temperature is to expel the water of crystallization combined with sulphate of lime, which is almost an invariable constituent of well and river waters. Note down the weight. The difference between the weight of the basin when empty and that of the dish and residue will, of course, represent the actual weight of the residue in half a gallon of the water. The residuum being thoroughly desiccated and weighed, place it on a platinum triangle, over a good gas flame, or the flame of a BERZELIUS lamp, and ignite until the blackening produced by the carbonization of the non-volatile organic matter disappears, and the mineral constituents are *white.* The time required to produce this change should be carefully noted. If nitrates or nitrites be present, as is invariably the case in waters containing sewage and other animal matters, then gently facilitate combustion of the organic matter, and the residue becomes white in a few moments.

On the other hand, if the water be contaminated with organic matter which has undergone but little decomposition, and especially if urine be present, the carbonaceous residue will require very lengthened ignition in order to consume the carbon. If it be necessary to heat to redness for any length of time, some of the carbonic acid in combination with lime and magnesia will be expelled, and consequently the loss of weight occasioned by the ignition would not correctly represent the actual quantity of organic matter. It is, therefore, necessary to *recarbonate* the lime and magnesia. This is done by moistening the residue with a few drops of a strong solution of carbonate of ammonia, and again drying it at 260° till it ceases to lose weight. The dish being now weighed again, and the weight noted, the difference will represent the quantity of non-volatile organic matter present with the mineral constituents. By the continued ignition which is necessary to burn the organic matter, the *silica* is rendered *perfectly insoluble.* To the residue in the platinum dish is now added a fluid ounce of water, and, drop by drop, strong hydrochloric acid—about one in two fluid drachms—until effervescence ceases. Particular attention should be paid to the odor of the gas evolved; if it smells of sulphide of hydrogen, this will be a further indication of the contamination of the water *by animal refuse.*

After the effervescence has ceased, the dish should be gently heated on a water-bath and the solution filtered. The silica left on the filter should be washed well with hot distilled water, till a drop of the washings, evaporated on a platinum knife, no longer leaves a trace of residue The filter containing the silica is dried, ignited in a weighed platinum crucible until the whole of the carbon is consumed, and then weighed. The filtrate from the silicic acid, after the washings have been added, is to be neutralized and made slightly alkaline with ammonia. The iron, alumina, and phosphates of the alkaline earths are precipitated, then filtered and washed with the same precautions as given in the determination of the silica, and when dried, weighed. As the iron, alumina, and earthy phosphates occur in water in very small quantity, rarely exceeding together a grain per gallon, it is for general purposes quite unnecessary to separate them. The precipitate produced by ammonia is usually recorded as *iron, alumina, phosphates.* After the precipitate is completely affused, and the washings are added to the filtrate, the lime is next to be thrown down, and this is done by adding oxalate of ammonia in excess; allow the whole to stand till the supernatant fluid becomes bright. Add the washings to the filtrate.

The precipitate is to be dried, ignited, and weighed. By ignition the oxalate of lime is converted into carbonate, and is weighed as such. The following decomposition occurs during ignition:—

$$\underbrace{\text{CaO C}_2\text{O}_3}_{\text{Oxalate of lime.}} + \underbrace{\text{CaO CO}_2}_{\text{Carbonate of lime.}} + \underbrace{\text{CO}}_{\text{Carbonic oxide.}}$$

As a portion of the carbonic acid of the carbonate of lime might be driven off during the heating, it is advisable to moisten the residue in the crucible with strong carbonate of ammonia, once or twice igniting after each addition, and taking the weight when it becomes constant. Fifty of carbonate of lime represent twenty-eight of lime. The washings being evaporated and added to the filtrate, about half a fluid ounce of a solution of phosphate of soda is added, and the menstruum allowed to repose for twenty-four hours in a moderately warm place. The magnesia is thus precipitated as phosphate of magnesia and ammonia—$2\ \text{MgO}, \text{NH}_4\text{O}, \text{PO}_5$. This salt must be well washed with dilute ammonia—one part alkali to six of water—dried, ignited, and weighed. By burning, the precipitate is converted into pyrophosphate of magnesia—$2\ \text{MgO}\ \text{PO}_5$—from which the quantity of magnesia is ascertained. One hundred and twelve of the pyrophosphate contain forty of magnesia.

Determination of the Alkalies.—The determination of the alkaline salts in water is generally omitted in ordinary analysis; but it must be acknowledged that when water is required for certain purposes, as for instance, for brewing, it is very important to determine not only the quantity of potassium and sodium present, but especially the form in which they occur, whether as chlorides or as carbonates. For brewing purposes it is usually considered that waters containing sulphate of lime are best suited for the manufacture of pale ales, since beers made with selenitic waters are paler than those made from water free from gypsum; but notwithstanding the presence of sulphate of lime, if potassium and sodium be there as carbonates, it is impossible to obtain a pale infusion of malt, owing to the alkaline carbonates extracting certain constituents which are not soluble in water free from alkalies. The following is the best method of determining the alkalies. Half a gallon or a gallon of water is evaporated to dryness in a porcelain dish in the usual manner. The residue is dissolved in hydrochloric acid, and evaporated on a water-bath to dryness. The soluble constituents are then extracted by water, and to the aqueous solution is added an excess of baryta water. After the precipitate has subsided, the solution is filtered, and to it is added a *very slight* excess of *pure* carbonate of ammonia. The excess of baryta thus precipitated is filtered off, and the solution which now contains only the alkalies, as chlorides, is evaporated to dryness in a weighed platinum dish, to determine the quantity of mixed chlorides of potassium and sodium. The weight being noted, the chlorides have now to be separated. This is accomplished by dissolving in water, adding excess of bichloride of platinum, and evaporating to dryness on a water-bath. The mixed platinum salts are now treated with alcohol and ether, filtered and washed with a mixture of ether and alcohol till the washings come through perfectly colorless. The precipitate of bichloride of platinum is then weighed, and the quantity of chloride of potassium it represents is calculated. This is deducted from the weight of mixed chlorides, the actual quantities of potassium and sodium calculated.

Having now determined the actual proportions of all the ordinary acids and bases present in the water, one has then to associate the acids and bases together as salts, in the form in which they probably existed in the water previous to analysis.

The association of the acids and bases is founded entirely on arbitrary rules, the usual plan being to unite them in the order of their respective affinities—the strongest acids with the strongest bases. But this is obviously an incorrect method, since it is often found that two chemists analyzing the same water will give entirely different forms of analysis, although they may both have found the same proportions of the respective acids and bases; the one will associate all the sulphuric acid with potassa and soda, the other may place it with lime, and regard the alkaline bases not as sulphates but as carbonates. Now, as before shown, it is a question of the greatest importance, when water is required for special purposes, to determine not only the proportions of acids and bases present, but the form in which they are associated. In order to do this properly the analyst must have regard—1st, To the geological characters of the source of the water; 2d, to the nature of the country through which it flows; 3d, to the contaminations from sewers and manufactories to which the water is exposed.

Rain-water, it is to be presumed, cannot differ materially in the nature and quantity of its impurities, but yet it has been shown that one rarely finds two river waters of precisely the same composition. In the water of the Dee, the analyst finds only about four grains of mineral matter, because the rocky soil over which it flows is soluble only to a slight extent in native water. The water of the Trent flows over a soil abounding in gypsum, and consequently the water is very hard, while in the water of the Thames, which flows through a line of country composed essentially of chalk, the prevailing constituent is bicarbonate of lime. The presence of a superabundance of earthy salts in water, exercises an influence of some importance in many of the industrial works of the kingdom, and especially in brewing. Paradoxical as it may seem, it is now an ascertained fact, that the hardest waters, that is, such as contain most earthy salts in solution, have the greatest extractive power for the brewer; and further, that the chemical changes that take place between certain constituents of the malt and those salts, serve in the case of ale brewing to fine the beverage in the natural way, without the aid of disgusting and corrupt *stuffs* employed for this purpose very frequently.

A glance at the composition of the waters which are used by **ALLSOPP** and **BASS**, the Great Burton brewers, and by **TETLEY**, of Leeds, *et cetera*, gives at once the clue to the superior excellence of the manufactures of these parties over ales made from such liquids as the *Liverpool Pike*, which is not only devoid of earthy salts in the requisite quantity, *but contains an amount of animal and vegetal matter in such a state of fermentation*, that the action is engrafted on the glucose, and proceeds in the tun collaterally with the alcoholic fermentation, which it ultimately modifies into the lactic and acid fermentation long after the natural ferment—the gluten of the malt—has been thrown off:—

	Burton water, Dr. Bottinger. Allsopp's brewery.	Leeds water, Tetley's brewery. Editor.
	Grains.	Grains.
Carbonate of lime,	15·51	19·78
" magnesia,	1·70	
" protoxide of iron,	0·70	0·93
Sulphate of lime,	18·96	4·97
" potassa,	7·65	—
" soda,	—	13·09
" magnesia,	9·95	9·73
Chloride of sodium,	10·12	7·11
" magnesia,	—	4·74
Silica and loss,	0·79	1·72
Total per gallon,	65·28	62·07

The quantity of calcareous salts in the above waters is a proof of the beneficial action of lime in the preparation of the best malt liquors.

ELECTRICAL PROPERTIES.—This article on water would be incomplete without making some allusion to its electrical properties, which are not only turned to useful account in the numerous and increasing applications of electricity, but also perform an important part in the great phenomena of nature. It would be improper, perhaps, to particularize under this head the hydro-electric machine, because although in that apparatus very large quantities of electricity are generated by the issue of steam through narrow apertures, the effect has been attributed by **FARADAY** to mere friction, and therefore exhibits no new property of the water itself. It is in the electricity which it generates by contact with oxidizable metals in the galvanic battery, and in the variable conducting power of the liquid according to its greater or less admixture with different acids and salts, that water assumes its chief importance in electro-chemical action. In the working of the battery, for example, it is the decomposition of the water which accompanies the oxidation of the zinc or other positive metal, and not the action of the acid or salt superadded, that really produces the electricity. This was demonstrated by **KOHLRAUSCH**, who showed that the electric tension was the same at the poles of two similar batteries, one of which was charged with distilled water and the other with a mixture of water and sulphuric acid. The remarkable effect of certain acids and salts in increasing the energy of the current, is chiefly due to the peculiar property which they possess of increasing the conducting power of the liquid. The following table exhibits this property in a very striking light:—

	Conducting power
Distilled water,	0·0125
Do. with 1-20,000 of nitric acid,	0·075
Sulphate of copper, saturated solution,	5·42
Sulphate of zinc, do.	5·77
Nitrate of copper, do.	8·99
Chloride of sodium, do.	31·52
Sulphuric acid diluted with eleven measures of distilled water,	88·68
Nitric acid, specific gravity 1·31,	93·77

From which it appears, that the addition of only one twenty-thousandth part of nitric acid to distilled water increases its conducting power about sixfold, and that one measure of sulphuric acid, added to eleven of distilled water, increases its conducting power seven thousand times. Distilled or absolutely pure water is therefore a very bad conductor of electricity; but it has been shown that water of this extreme purity is not to be found in nature; that even rain-water is more or less impregnated with certain foreign ingredients, and that the waters of rivers and wells vary immensely in the amount and character of their saline constituents. It is therefore that, in rainy weather, the moisture of the atmosphere, acting the part of a conductor, destroys the insulation of the telegraph wires, and obstructs the working of the instrument; it is therefore that the earth, and still better, the briny waters of the ocean, not only transmit natural currents, but submit themselves as willing agents to the purposes of telegraphic communication; and lastly, it is to the moisture of the atmosphere, floating in clouds charged with an opposite electricity to that of the earth, that the grand phenomena of the thunderstorm chiefly owe their existence.

WINE.—*Vin*, French; *Wein*, German; *Win*, Anglo-Saxon; *Wyn*, Dutch; *Vino*, Spanish and Italian; *Vinho*, Portuguese; *Vinum*, Latin; *Oinos*, Οινος, Greek. —All these denominations were probably derived from *Oinos*, with the digamma prefixed, answering to F or V in English, as *Voinos* and thence the Latin *Vinum*. The Hebrew term for wine in general, is *Yayin*, but if medicated or, in other words, made more potent by the admixture of herbs or drugs, it was denominated *Shekhar* or *Strong Drink*, in common with other fermented liquids. The Greek name being the parent of the Latin, confirms the tradition that wine came into the more Western parts of Europe from Greece by way of Italy, and from Asia into Greece.

When man was driven from that peaceful asylum originally assigned to him by his Creator, and condemned to earn his bread by the labor of his hands, his attention was no doubt powerfully exerted in procuring the necessaries of life; such as food, clothing, and habitation. As a cultivator of the earth, he must have been constantly employed, and, as his occupation varied with the seasons, his mind was continually disciplined on contrivances to diminish and sweeten his toil. His activity, when thus excited, soon extended its influence to every department of life, and having procured its necessaries, he was doubtless early led to task his ingenuity in the attainments of its luxuries. Among these, the preservation of fruit and their juices, however rudely practised, might have led to the use of inebriating drink—a beverage which was discovered by some of the most savage nations, and is deemed a luxury by the almost universal testimony of mankind.

Wine, when an uncompounded word, signifies the fermented juice of the grape only; but when compounded, it is applied as a general term to the fermented product of other fruits in conjunction with the name of those fruits, tendrils, stems, leaves, or similar substances from which it is made, as gooseberry-wine, ginger wine, and all the varieties denominated *domestic* wines.

Wine of the grape is divided into dry and sweet, and under one or the other of these great divisions every variety is included. The characteristics and causes of each of these divisions will be fully explained.

The juice of the grape, which is usually called *must*, is known to ferment *per se* at 70°, which proves that wine was very early known, particularly in hot climates, where drink is so much required to allay thirst; and this is a further sign that the vinous fermentation was familiar long anterior to the deluge.

Carrying this idea still further towards the Creation, Milton seems to have entertained the opinion that the fruit of which Adam and Eve had eaten—

> ———— whose mortal taste
> Brought death into the world, and all our woe,

was of an intoxicating nature, when he says:—

> Soon as the force of that fallacious fruit,
> That with exhilarating vapor bland,
> About their spirits had played, and inmost powers
> Made err, was now exhaled.

Wine is the oldest fermented liquor, its invention being ascribed to Noah in the traditions of the Jews almost immediately after the deluge. The Greeks with their fabled Dionysius from Egypt, originally from India, threw no light upon the discoverer; but if they learned the art of making wine from the Egyptians, that liquid may be thus traced up to the days of Moses. Herodotus reports that there was no wine made in Egypt, a singular error, when Mareotic and Tæniotic wines were notorious. The wine of Meröe called *indomitum* by Lucan was far-famed. The writings of Moses show that the kings of Egypt drank wine, as all who have perused them will not fail to recollect in reading the story of Joseph and the chief butler of Pharaoh. The ruined temples of Thebes also display the emblems of the vintage in bas-relief, and figures of men pressing grapes with their hands, the must flowing into goblets emblematic of the wine-press. Some have used this as an argument against fermented wine; but must unfermented, would not keep from decomposition for many hours, even in the Eastern land of miracles; nor would the simple juice have intoxicated Noah, because to occasion ebriety fermentation is absolutely necessary, as in all other alcoholic liquors.

Next in antiquity to the volume of the Jewish faith are the works of Homer and Hesiod, who lived so near together in point of time, that even concluding Homer to have flourished in the tenth century before Christ or about the reign of Solomon, the difference so much discussed by the learned is of no moment in a scientific sense. Homer mentions the names of several kinds of wine, and alludes to their potency.

The frequent allusion to wine, the praises bestowed upon it, the flowing goblets, the luxurious banquets as described by the great Grecian poet one thousand years before the Christian era, exhibit its value and his attachment to the comforts of the table and to jovial society.

Horace was of this opinion when he says—

> Homer, in praise of the profuse,
> No doubt loved well the balmy juice.

The wines referred to required twenty parts of water to make them potable, as in the case of the Maronean ones. Poets are not to be literally trusted; and in the present case, as the object of Homer was to intoxicate the giant Polyphemus through his hero Ulysses, full latitude must be given for poetical fiction, which can seldom be quoted in reference to the exact sciences. This Maronean wine was made from vineyards on the side of Ismarus, a hill of Thrace, by Maron a priest of the Sun. The circumstance of the Greeks mixing water with their wine, might after all mean no more than it does in France at the present time, where water is often mingled with common wines of the country by no means remarkable for their strength. Thus the wine of Scyathos is said to have been used with half its bulk of water. The wines most in repute with the Greeks were, in the first place, the wines of Chio or Chios, which, with the Thasian, were ranked among the superior growths. Lesbos was also celebrated for its wines. Many of the Greek islands were distinguished for wines of delicacy and flavor, for the most part rich and sweet. The Ariusian wine of Chio was in high esteem as a luscious product of one of the vineyards of the island. The Pannonian was celebrated for its healing qualities. This wine was red, from a vineyard in Lesbos. The wines of Rhodes, Crete, and the Clazomenian from the shores of Ionia, were much valued, and often taken with an admixture of sea-water, a singular custom, thought to impart smoothness to the wine. The quantity thus mingled was very small, and was always boiled before it was mingled with the wine. The Greeks classed their wines, as in modern times, into sweet and dry, but had an intermediate species. They seem to have preferred the thick sweet wines to all others, that species, for example, which the moderns denominate malmsey, differing little perhaps from the modern wine of Cyprus, or the malvasia of the Morea. Some of these wines possessed what is now called the bouquet. As soon as they were opened to the air, the perfume was immediately perceived, but this might have arisen from the infusion of odorous substances at the time of fermentation, a practice then common. Saprian wine was one of those celebrated for its odor on being uncorked. This odor, it is pretty clear, did not arise, as it does in the pure wines of France in modern times, from the natural perfume after fermentation, but from the addition of odorous substances. Port and the strong Anglo-medicated wines at present, possess no bouquet from its being destroyed by the admixture of alcohol with them artificially, rendering them heavy and dull. The wines of Bordeaux, Champagne, and Burgundy, on the other hand, have the perfume in a high degree from nature.

The wine of Chio, called the Phanean, was celebrated among the Romans, who imported both that and the wine of Argitis. The wine of Mende in Thrace was a white wine of no great strength. The wines of Zante speedily intoxicated; and those of the other Greek islands, as well as of Lydia, Phœnicia, and Cilicia on the mainland, were of good quality, producing growths the mere names of which it would be superfluous to record.

Rome, as she learned the other arts from Greece, acquired also that of making wine, as soon as she extended her power beyond the limits of her home empire. In the days of HOMER milk was substituted in the sacrifices in place of wine, because of its scarcity at Rome. The wine first made seems to have been from the grape grown in the Campania Felix. The most celebrated sites for the vine were near Naples, on the sides and at the foot of Vesuvius, now covered with the lava and ashes of that celebrated volcano; a spot in which Bacchus was said to have delighted in consequence of its rare fertility and excellent adaptation for the vine culture. The sea washes the limits of this beautiful vine-climate in one direction, and in the other delightful hills, named the Falernian, Surrentine, Massic, Gaurean, and others, arose with the choicest aspect and the most propitious slopes from the low country, giving names to the products since wedded to immortal verse. Thus the Falernian, Surrentine, Cæcuban, Setine, and other wines of the vicinity, were named from their native hills. One or two of the more celebrated writers left passages in their works which enable us to give a guess at the nature of some of the wines in use among the Romans, whether the growths of Greece or Italy. It is certain from these that, except in the sweet wines of the South of Europe at present, no great similarity could have existed between the ancient wines and those most prized by the moderns. The writings of ATHENÆUS and PLINY give a tolerable account of the treatment of the vine under cultivation, but we learn little from them in relation to the constituent parts, flavor, or qualities of the produce. The same remark will hold good in relation to the extant works of VARRO, CATO, COLUMELLA, and PALLADIUS. In short, no source remains from which any tolerable approximation can take place as to a knowledge of quality and flavor. It is well known on the other hand that the Campanian vine once enriched a considerable territory of great fertility, and that a number of large towns which have now disappeared, once adorned that favored spot. The more famous wine was the Falernian, which some suppose to have been made on the present Monte Barbaro. The Cæcuban, a sweet wine, was made on the palmus lands of Amycle. The Falernian was of three kinds, the dry, sweet, and weak. A celebrated vintage called the Opimian, from the name of the consul that year, L. OPIMIUS NEPOS, took place in U.C. 632, the wines of which bore a great price a century afterwards. The Falernian required nine or ten years to ripen, and when aged was bitter. Some have imagined it was a dark red wine, others that it was white. The Surrentine wine was durable, and generally taken out of cups of the same name. The Massic came from Sinuessa; Trifoline from a hill near Naples; Tarentine from Mount Aulon, near Tarentum; Alban from a hill near Rome; Mamertine from Sicily, near Messina; Cereton from Etruria; Signian from Latium; and Massican from the Abruzzo. The vicinity of Rome also produced the Nomentan, Sabine, and Venafran wines. The north of Italy produced no wines of note. Spain sent the wines of Tarragona to Rome, and France those of Narbonne, Marseilles, and Vienne; but these were said to flavor too much of the smoke of the *fumarium*, or else of pitch.

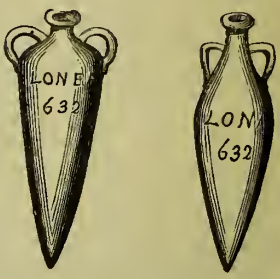
The Romans suffered their vines to grow high and weakened the must. How the fermentation was managed nowhere appears. The wines were placed in a smoky receptacle to ripen, the object being the same in ancient as in modern times, to assure maturity. The Carthagenian MAGO, who wrote five hundred and fifty years before CHRIST, says, that to make the best wine, that of the sweet or luscious species, the bunches of grapes were gathered when shrivelled by the sun's heat, the bad fruit picked out, and they then were placed upon a frame of open-work covered with reeds, exposed to the sun by day, but sheltered from the dew at night. When they were sufficiently shrivelled they were thrown into a cask and trodden, and thus the first must was made. When drained, they were submitted to the wine-press for the first wine. They were then trodden a second time, and cold must added to the pressing. This second wine was placed in a pitched cask, to prevent it from becoming acid. After it had remained for twenty days in this state it was racked into another vessel, closed up from the air, and covered with a skin.

Such was the ancient mode of making sweet wines of the luscious malmsey species. For the wines in general, the fruit was gathered at intervals as it ripened, and carried to the press in baskets. The must was received in a stone or plastered cistern, and the fermentation was completed as quickly as possible. The process, there is reason to believe, was not very different from that hereafter described. In certain cases the fermentation appears to have been unnecessarily prolonged, and a part of the must that flowed from the grapes by their own pressure was reserved in a separate vessel and set aside, as it is the custom to do now in making Tokay-Ausbruch in Hungary. This must, the most valued, was often stored by itself. Sometimes it was plunged, when in a state of fermentation, into deep water, being previously hermetically sealed. Weak must was often boiled down, so that much of the aqueous portion evaporated, and it was denominated according to the quantity of the portion unevaporated. If two-thirds were left, it was called *calenum;* if only one-third, *sapa.* This was evidently copied from the Greeks, and is still practised, being called in Italy *vino cotto*, and in France *vins cuits.*

The custom of adding sea-water to wine is said to have been discovered by accident. The water was boiled down to a third part, but the quantity used differed according to the nature of the wine. The act of perfuming the wine must have ruined its delicacy; pitch, rosin, cassia, myrrh, saffron, and cypress leaves were, one or the other or several of them, thus infused. The true principles of fermentation were evidently unknown to the ancients, who had not the advantage of modern chemistry. It was the same with the causes of the difference between dry and sweet wines. There was no deficiency in the attention paid to the vines, except that they were permitted to weaken themselves by too luxuriant a growth; this in consequence tended to aid acetous fermentation. In aspect, soil, grafting, and training, all seems to have been well known in ancient times; the Greeks understanding this point better than the Romans. The Aminean grape was the species most cultivated for wine, at least in the Campania Felix, but it cannot be identified with any modern species. October was the vintage month.

The treatment of the ancient wine after the first fermentation included a further progress in the vat, and it was then placed in earthen vessels, hermetically sealed, denominated *amphoræ*, each of which held 6·7827 English gallons, or in other vessels of a different capacity, as the *urna*, which held just half the quantity of the amphora. If an inferior wine, or one designed to be carried to a distance, it was placed in pitched skins—the bottles of the New Testament. When designed for the amphora and cellar, after being exposed to the smoke of the *fumarium*, it had the year of the vintage or the consular year marked upon it, and was set in the ground. Under this treatment in the *fumarium* and elsewhere, some of the wines grew so thick that they could not be drank until they were dissolved in water. That sometimes the wine tasted of the smoke is not matter of wonder. It is well known that Madeira ripens rapidly if the bottles are plunged into a hotbed or into stable dung. The amphoræ were vessels without bases, shaped as in Fig. 615, and made of pottery clay. The consulship of the famed Opimian year is marked on some of the existing amphoræ in the way thus exhibited—L. O. Nepos, u.c. 632. The wines of the ancients were thus different in quality from those of modern times, and could only have been relished by long habit. The different varieties which have been transmitted by name in Italy, Gaul, and the East are reckoned at a hundred kinds, rough, soft, and sweet. That the wines of the ancients were more durable from this after-management than from any knowledge they possessed of their chemical combinations when treated scientifically according to their nature, and unmingled with substances foreign to them, is evident upon a due consideration of the subject.

Fig. 615.



Regarding the wines of Asia Minor, little is known in respect to the treatment. Some kinds were kept in the *fumarium* until they became as hard as salt, and it was necessary to dissolve them too in water before they were drank. The prices they bore, considering their age, were not extravagant; those more than a century and a half old costing less than seven shillings the English quart. In Rome the quantity of wine consumed was considerable. The servants of Cato were allowed about a pint and a half per day. The stocks of the more precious wines kept by the opulent were surprisingly large. Of the best and dearest Greek wine, that of Chio, Hortensius left ten thousand casks at his decease. The celebrated Mæcenas introduced a rare wine of his own, called mæcenatianum. Of the common wine made in Italy, too, the produce was large, being in one recorded case no less than two thousand one hundred and fifty gallons per acre, or eight *culei* on the jugerum or twenty-eight thousand eight hundred square feet. In these computations, however, there is much uncertainty.

Wine was drunk in Rome out of murrhine cups when the eternal city was in its greatest height of luxury and pride. What this substance was is unknown, but it appears to have come from Egypt or the East, and to have possessed an inherent perfume; many dissertations have been written upon its nature, all alike unsatisfactory.

Among names of ancient wines, is that of Helbon or wine of Tyre, called by the Greeks *kalibonion*, and alluded to by the prophet Ezekiel—the name meaning sweet or fat; it was made near Damascus, originally by the Persians. This wine was common in England in the reign of Richard III., being imported in Venetian vessels. The wine of Lebanon in Hosea, is praised for its perfume. But the different conjectures regarding the nature of ancient wines, built upon no satisfactory data, cannot, any more than their names, be of any real moment, however amusing to the scholar. It may be observed, however, that a marked distinction anciently existed between pure wine, and that which was perfumed or medicated, as with certain wines imported into England, brandy is added for the same purpose, particularly to port wine. The Jews have preserved this distinction in scripture, by using the term *mixed* or *strong wine;* thus—In the hand of the Lord is a cup, and the wine is red; it is *full of mixture;* and he poureth out of the same; but the dregs thereof, all the wicked of the earth shall wring them out and drink them.

Leaving a subject so much of which must be conjectural, the wine of the present time, naturally the most important, comes to be considered, together with the processes adopted by the moderns in its manufacture. The variety of the plant which produces it, and the nature of the soils in which the best grape is matured, are subjects copiously treated of both by French and Spanish writers. In the catalogue of the national collection of vines at the Luxembourg in Paris, there are five hundred and seventy varieties, classed black oval, black round, white oval, white round, grey and violet oval, and grey and violet round. Chaptal collected fourteen hundred sorts, and Clemente states that two hundred and fifty species exist in Andalusia alone. The treatment of the vine and the entire culture of the plant belong to the rural economy of the wine-producing countries. To enter largely upon this subject would be out of place here; still the following on the kind of soil best adapted for the grape, and on the best description of grapes to employ, will interest and instruct the reader.

The wine-producing countries in the Northern hemisphere are included between the parallels of 33° and 51° North; but this rule is limited by local circumstances, probably by the line of the biting North-east winds, which keep back the vine in spring. An oblique line drawn a little north of Coblentz, concave to the North, and continued to the mouth of the Vilaine, in 47° 25′ North, will nearly define the vine limit. Wine once made in good quality at Estampes and Beauvais, so as to be celebrated, cannot be made there now. Thus it was once made too in the counties of England South of Cambridgeshire. Wine in 1553 was made of the muscat grape at Mâcon in Burgundy, where it cannot now be made at all. In Asia no good wine is made South of latitude 33° North, in Persia and Shiraz. In regard to the Southern hemisphere, except a little sweet wine from the Constantia vineyards at the Cape of Good Hope, none of any mark is yet produced, though much of an inferior quality is made. With the wine-producing countries of the North the world is too familiar to need the exact enumeration.

Keeping in view wines of the first and second class in excellence, nearly all which lay claim to the greatest delicacy and purity are produced in France, where science and long experience have been brought to bear upon their management. In a first-class wine there must be no mixture of any foreign matter whatever. The fermentation must be natural, and no extraneous substance introduced, not even brandy. Nothing must be allowed to prevent the development of the perfect character of the particular species expected — lightness, freshness, a rich odor conferred by nature, such as are found in Romanée-Conti, Chambertin, Vin du Roi, or Hermitage of the first class, because of such wines only can the term *pure wine* be understood, or a standard be found by which the first-class can be established, and the test be fixed for the inferior kinds. France, Spain, Germany, Italy, Portugal, Hungary, Greece, and Sicily are the principal wine countries of Europe. Tolerable wine has also been made in the extreme South of the Russian dominions.

Passing over the vine culture, the best sites, the diseases of the vine, the training, and the incessant and laborious calling of the vine-dresser, all belonging, as before observed, to rural economy; and therefore only observing that the practice of grafting is pretty general —it may be added that some vines will bear well for a century and a half. There have been examples of three centuries, while others will not be productive for more than forty years.

The extent of the vineyards that produce the finer wines is well known to be very limited. The differences of soil and treatment do not appear sufficient to account for this fact. Although the best vines are grown on a calcareous soil, as on the chalk hills of Champagne and the albarizas of Xeres, of which carbonate of lime forms two-thirds, and in three-fourths of the more celebrated vineyards this is the case, though the necessity of such a description of soil has been denied.

In the vineyards of Andalusia, while some of the above soils contain even seventy per cent. of carbonate of lime, the remainder is a compound chiefly alumina, with a very small portion of silica, and sometimes a little magnesia. In certain spots the soil is almost pure carbonate of lime. This kind of earth absorbs every particle of moisture which falls upon it, and never cracks nor opens in the hottest summers. The albarizas are a series of calcareous hills. The best Spanish wines produced on such a soil, exhibit its virtues very strikingly in the fineness and durability of the product, and militate against the opinion expressed in some districts, that if the soil be porous, light, and free, the presence of lime is of little moment. The fences of the vineyards on the albarizas consist of the prickly pear. Adjoining the albarizas, or chalky soils, come the arenas, or sands; but these are intermingled, more or less, with calcareous particles. About Malaga, where the surface of the country is extremely rugged, the soil consists of limestone, intermixed with slaty schist, over which the rich raisins for export are produced. In the South of France, in Rousillon, the soil resembles that of Malaga, particularly near Perpignan, being slaty schist, or gravel, interspersed with calcareous matter. In some places where the soil is not six inches thick, a hole is bored in the loose rock with an iron bar, in depth about a foot, into which the plant is thrust, among the stony and arid ground. In Burgundy the soil varies much. At Chambertin it is a brown loam, full of gravel, and friable. This gravel consists of small pieces of broken limestone, in some places; in others, of marl with small shells—while, in another place, the vines grow in pure clay, but still with traces of lime in some form. The champagne district, in like manner, is almost wholly calcareous, at least where the best wines are made. Thus the famous sillery is produced from vineyards on chalk, with an Eastern exposure. At Ay, on the Marne, on both sides of the river, the hills are chalk, and the soil often supported by terraces. *By the river of Marne, and on the hills of Rheims are the celebrated localities*—proverbially so. The chalk, whether it lie deep or superficial, produces the same effect in respect to dry wine of superior quality, agreeably to its treatment and the aspect of the vineyard. The hermitage wine has been cited in proof of the goodness of wine grown on the debris of granite.

Wines of the finest quality are undoubtedly grown upon soils where lime is not immediately visible. Sands in the vicinity of Bordeaux, and granitic soils near the Rhone, flinty and argillaceous earths, are found to produce excellent wine. But hermitage, for example, although produced from vines grown among fragments of granite, is no doubt affected favorably from the calcareous soil hard by, having portions intermingled with them; nor can it be any exception to the fact as respects the finer dry wines, that their superiority is due to their connection with calcareous matter. Sweet wines are produced in almost every kind of soil. Dry wines produced on schist, for example, are poor, compared to those the fruit of which is grown on chalk land; while the sweet wines, such as those of Malaga, are good on that description of soil. The Rivesaltes, a sweet wine of France, is produced on granitic land upon which lies a stratum of pebbles, while the dry wines of the same land which produces those celebrated growths, are sufficiently mediocre. At Ay, where the finest champagne is made, the soil lies upon chalk in some places from ten to fifteen feet thick; but the superincumbent earth is full of pieces of chalk, the surface only being argillaceous; and where most so, causing some difference in the quality of the wine. Very little manure is applied to the vines that produce the best and finest wines. In argillaceous soils the roots of the vines are found not to branch off in a desirable manner; and the facility with which the soil retains the water, causes a degree of humidity prejudicial to the bud. Volcanic soils, on the other hand, give excellent wines, particularly when they are of very ancient date, and rival those the fruit of which is grown on calcareous strata; generally, too, possessing a flavor peculiar to themselves. In all cases the soil must be light, friable, porous, so that water shall not lodge around the plant. The exposition may vary. Bacchus *loves the hills* is an old, but not an unexceptionable adage, as gravelly plains may produce good wines. Sometimes, according to the nature of the country, an Eastern aspect is best; at others a Southern, and even a Northern has yielded excellent wine; much in such a case depending upon the latitude and the more obnoxious winds, as well as the atmospherical temperature. It is remarked, however, that good wine is rarely produced in narrow valleys, especially if a river flow through them.

It will thus be perceived that the nature of the soil for the dry and finest wines must be calcareous, even to pure chalk; in all events it must be sufficiently so to influence the vine most essentially during its growth; and that for sweetand luscious wines, the nature of the soil is of far less moment, such wines being grown on every kind of soil, except that which produces the most valuable and rare dry growths. In the English colonies, and in the United States of America, not long ago covered with primeval forests, the soil, enriched by the autumnal spoils of ages, is too good for the vine, the fruit of which, for making good wine, differs so much from the character of fruit in general, when intended for the table.

The grapes are various that give out the more precious must. In Rousillon in France, the best wines are from the carignan, grenache, and mataro grape. The celebrated Rivesaltes wine is principally from the white macabeo, the muscat, and grenache blanche; the hermitage comes from the scyras or ciras grape, the roussette, and the marsan. The pineau blanche and pineau noir before mentioned produce the celebrated Clos Vougeot wine in Burgundy. In the Bordeaux wine district, the Graves, Barsac, and Sauterne, come from the white sauvignon, the semillon, the rochelin, blanc-doux, and primeras—all three white—and the black muscade. The best Spanish wines are the produce of the pedro ximenes grape, both at Malaga and Xeres. At Malaga and Grenada one half the plants are of this species; at Xeres, one-eighth; at Motril, four-fifths; and at Paxarete, one-fourth. The grape, giving fine wine in the North, may be productive of wine of very moderate merit in the South. In consequence every country, and even district of the same country, differs in the variety of the fruit prepared. This arises naturally from the circumstances of the temperature and soil affecting one species more than another, for which it may have less affinity. The growths are often mixed. Thus the marsan grape of itself gives a sweet wine, and the rousanne or roussette a dry, therefore they are mixed to prepare the white hermitage, for example. In Burgundy the black pineau is much used, as well as the chandeney. In champagne the norien and pineau prevail, with some of the gamet and gibaudot. The black morillon, and the magdelaine, and the meûnier, are early bearing species. The chasselas, supposed to have come from Cyprus, the cioutat or black grape of Corinth, the muscat noir, isabelle, verdet, and black muscade, the carbenet, violet, and corinth in France, the Uva del Rey, the mollar, the listan of Xeres, the larga and doradillo, with the moscatel gordo, are used in different proportions in some places in Spain, but one kind rarely or never alone. To enumerate and describe the five hundred and seventy species in the garden of the Luxembourg in France, could not enable a cultivator to discriminate what species would be best to adopt, so much depending upon site, climate, and annual temperature. The grenache blanche, for example, is only used in the district of Collioure in France. The Hungarian varieties also are numerous; but site and experience can alone determine, as elsewhere, the species most in accordance with the views of the cultivator in producing the best wine.

By a remarkable peculiarity, nature, and habit of the vine, it adapts itself to those parts of the country which are least fitted for the cultivation of the cerealia. Those vines which bear the best fruit for the finest dry wines, invariably grow on soils which would be unproductive with respect to the food crops. Gravel, sand, volcanic debris, flint, and such like soils, are favorable to the growth of the vine, whilst rich, deep, warm, fat earth, and all rich lands, are unsuited.

The names of the different kinds of vine fruit in Hungary are so untranslatable in the West of Europe, and so far off, that they can hardly be identified with those of the West without inspection by qualified cultivators. Thus the Furmint is used in making the Tokay-Ausbruch in the Hegyallya; the Fejér-Szöllö of the same district; the Szemendrian or white Servian grape; the Sár-Fejér or honey grape, believed by some to be the magdalen; the Balafant, the Rók-Szöllö or silver white; the Zapfner which, some contend, is identical with the Orleans of the Rhine; the Härs-Levellü or linden-leaved; the purple Kadarka or real Hungarian; the Blue of the Banat, the Csoka, or Sloeblack, and a great variety of others, which it would be useless to name, are grown to produce the celebrated wines of Hungary.

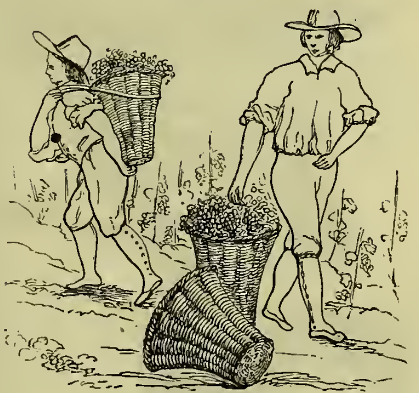
The climate of Hungary is peculiar, and in extremes; so that, in some places, they are obliged to bury the stocks to keep them from the cold. The cellars are badly built in many places, and the casks too small, and new and unseasoned wood is continually adopted, spoiling the flavor of the wine. Marble store-vats are used in many places; one at Ofen will contain thirty-nine thousand gallons. That wines ripen best in a large volume, is proved in this district by these vats, or rather cisterns. The wines of the plains are inferior to those of the hills from the same description of fruit.

In Germany, the Riessberg, a small white grape; the Kleinberger, a very productive species; and the Orleans grape—make the more celebrated wines. The Orleans is the favorite at Rudesheim; but all the other wine-makers, except at that place, throughout the Rhinegau prefer the Riessberg. The grapes for the Joannisberger of the first class are carefully selected, and only a small quantity is ever made; about sixteen aums of thirty gallons each. The black pineau of Burgundy, and the teinturier are grown on the Rhine, as well as the chasselas. The traminer, white clüvener, franken, gutadel, frühroth, black cluvener, and muscatelles, are cultivated to a considerable extent in Germany, and on the Moselle, where only the kinds adapted for a Northern class of wines ripen well. This may suffice to afford a faint idea of the great extent to which that portion of wine-making connected with agriculture must be carried, to embrace the entire subject over an extensive and ever varied field.

The grapes depending for perfect maturity upon their Northern or Southern latitude, the vintage takes place accordingly in September or October. Upon the excellence of the must rests the purity of the wine, and that depends much upon the season, the character and soil being the same. The utmost development of saccharine matter is watched until the fruit is ready to burst with ripeness, if all goes on well. The sun having dried up the dew, the work commences; the gathering being expedited most in warm weather, because the fermentation is then most active; and it is desirable to ferment at once the largest possible quantity of must.

The riper clusters are separated from the branches when the skin is thin, transparent, and not apt to break between the teeth; when the color is become deep, that is, when, if the grape be of a white sort, it becomes grey, or if red, from a violet hue appears black; when the stem is woody in fibre, losing its green color, and becoming brown like the main stock, the grape hanging loosely; lastly, when the grain gives way easily to the pressure in gathering, or when crushed, has a vinous odor. The bunches are gathered with great care, for which purpose scissors are commonly used, in order to shake the fruit as little as possible; as the ripe grapes are easily detached, and are bruised with the slightest fall. The baskets—Fig. 616—in which the bunches are placed are small; and the deposition in them takes place with great care lest the fruit be injured. With large baskets the grapes are crushed; and the must is too often wasted, owing to the superincumbent weight. All the bad or green grapes must be taken off and put aside, as the unripe are apt to impart acid to the sound must. The grapes in different states of maturity are not to be mingled, because they cause an inequality in the fermentation of the must by their acidity, and consequently it is deteriorated. The baskets of osier of a peculiar make are carried to the press strapped on the backs of men, or in carriages. The backs of men, or even of animals, are preferred to carriages, because the motion is less. The stems of the clusters are cut short off. Some farmers take the grapes off the clusters, an operation in France denominated *egrappage*, but the practice is by no means uniform, nor is it universal.

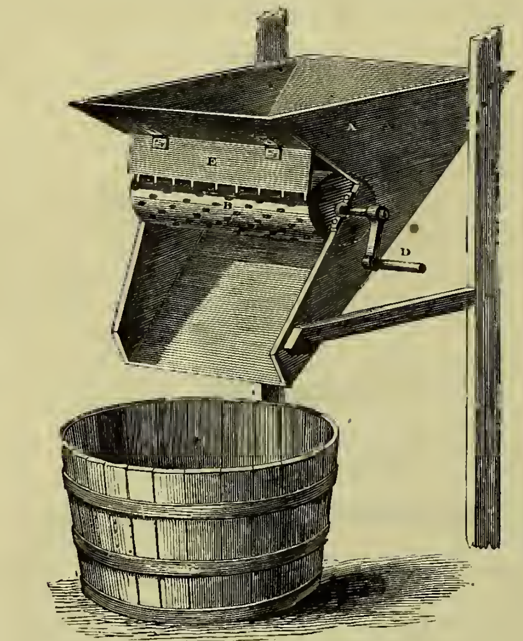
Fig. 616.



Osier baskets and mode of carrying the grapes to the press.

The next part of the process is treading the grapes, or breaking them with machines, before they are set to ferment. This operation facilitates the fermentation. Square troughs are used, having holes in the bottom to admit of the must flowing out. The grapes are then trodden by men with sabots or wooden shoes, at the best, though an ancient, a clumsy, and not very agreeable operation. The must which escapes is thrown into the fermenting vat either with or without the murk, as may be required; and the same operation is repeated until the whole is trodden. The disengagement of the coloring matter from the skins is mainly effected by this process, and no substitute would answer which did not obtain that object. The subsequent fermentation and the heat it produced would not alone obtain and fix the color; the skins must be broken. Several inventions have been exhibited and others carried into practice to meet an end so desirable. Of these machines at a reasonable cost, one is the invention of M. Acher of Chartres, and has the recommendation of being among the cheapest. This machine is shown in Fig. 617. It does its work well, having the recommendation of the more experienced of the winemakers that it was capable of giving the must the utmost effect of which it was susceptible, before submitting the grapes to pressure. All were found to be equally and uniformly crushed—none escaping the action of the cylinder. By its use the fermentation proceeds in a more uniform manner, and the action of the press becomes more effectual. A, a hopper in which the grapes are placed; B, a cylinder, one metre in circumference, and sixty-five centimetres in length; it is armed with small nails; the heads large and flat, placed in curved or oblique lines on the cylinders, distant from each other five millimetres. This cylinder is placed beneath the hopper, to crush effectually all the grapes which descend to it. The cylinder is turned by a handle, D; E is a species of wooden flap armed at the lower edge with a series of teeth, perpendicular to the axis of the cylinder, disposed in such a manner as to play between the nail heads on the cylinder, and to crush all the fruit which approaches it; F. the vat which receives the must when crushed.

Fig. 617.

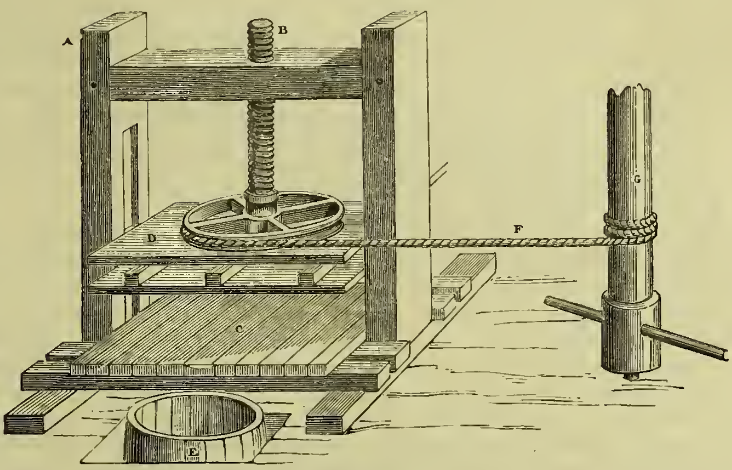


There is another French invention for the same purpose by a mechanic of Toulouse. It consists of two horizontal cylinders, which act in the same mode as those of a laminating engine, not only by pressure, but by friction. It moves by means of two toothed wheels attached to one end of each cylinder. In order to communicate to one cylinder a movement more accelerated than that of its fellow, the diameter of each wheel as with its cylinder, is different. A handle is fixed to the end of the smaller cylinder. The larger is ten inches in diameter; the smaller six. These two cylinders are placed at the bottom of a hopper, in which the grapes are deposited. The whole is constructed over a cask or vat, five feet nine inches in diameter, or in length, if of a different form from that of a cask, and this receives the must. It is effective, and dispenses, equally as well as the machine of M. Acher, with the old uncouth mode of treading out the fruit with sabots.

In order to prevent white wine from becoming colored, the red grapes are not trodden, because it would bruise the skins and discharge the coloring matter; but they are submitted to the press, as they arrive from the vine, and then taken to the vat, husks and all in some places; in others, the murk is reserved after the first pressure. The mode adopted in the use of the little press, which is directed rather to make a little choice than a large quantity of a middling class of wine, is as follows:—Planks are laid upon the bottom of the press, which is uneven, so that the must may run into one channel, and thence into a cask placed below the level of the floor of the press. The grapes are carefully piled on the *maye* or planks at the bottom of the press, other planks are laid upon the grapes, then several transverse beams of wood, and upon these the press is screwed down. The pressure at first is but slight, that there may be no waste of the must. The pressure is then increased until the utmost force of the screw is exerted, and the murk becomes as hard as a stone. The press is afterwards relaxed, the edges of the hardened mass cut square with an instrument for that purpose; and the cuttings being heaped upon the top, the screw is again applied, and the wine thus produced is called, *wine of the first cutting*. This pressing and cutting are repeated more than once. Finally, the murk is steeped in water, and again pressed, when a small wine is the produce, given to the laborers, called in France, *piquette*, and in Spain, *agua pié*.

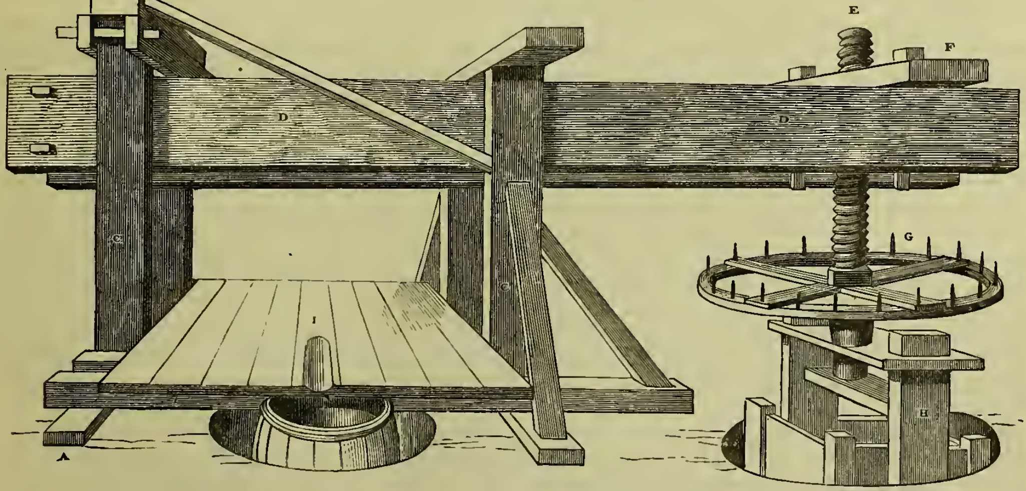
The wine-press, an instrument as old as the days of the Israelitish lawgiver, is made in various modes in the same country. In Spain at this day presses are clumsy troughs, about eight feet square and a dozen inches deep, with a wooden screw in the centre. Into such a trough, in Andalusia, the grapes are carelessly flung, with a sprinkling of powdered gypsum in making white wine, to saturate the malic acid. The must is received in jars from holes in the trough, and carried thence to the butts. A bar or lever, of about five feet long, is used for turning the screw. The wine-press used in France for the hermitage wine, is a trough seven feet square, having an iron screw of vast power in the centre. This is turned by a wheel having projecting spokes for the workmen to pull it round. There is a stage round the press for the workmen to stand upon. The grapes are built up in the trough as high as the screw will admit. The must flows from spouts in the sides, at the bottom of the trough. Wine of the first cutting is then taken. This press will make at once forty casks of wine, of fifty gallons each. The murk is generally distilled. In Burgundy, the trough or place for the grapes is twelve feet square, having a lever worked by a wooden screw. There is the *Bascule*, a large press requiring a dozen men to work it. The *Pressoir à étiquet*, moved by levers, or a horizontal wheel worked by four men; and the *Pressoir à coffre*, single and double. One in a vineyard in the Saone and Loire acts by percussion. This press is novel, and is the ingenious invention of M. Réveillon. The press before spoken of as used for making a small quantity of choice wine, in use in France, almost universally, though now somewhat improved, is here represented. In making white wine with red grapes, the want of care in the carriage of the fruit to the press, and the previous pressing, will sometimes cause the wine to assume a tinge of red, which, though slight, is very perceptible, and hence the epithet of *Partridge-eye* has been applied to it. Of course the quality of the wine is in no way altered by this circumstance. There is but one species of grape, the tintilla, which has a colored pulp. The grapes for the red wines thrown into the vat after being trodden, bruised, and evolving these colors before pressing, it becomes fixed by the heat of the fermentation. In some wines there is apt to be an astringency from the tannin in the stalks, attributable to the desire to preserve the tint; the stalks being acted upon by the heat of the wines, as well as the color in the skins.

Fig 618.



Gypsum cannot be used in red wines without injuring the color. It is often esteemed preferable to carry out the vintage process in the hottest sunshine, where the external heat upon skins is found as effective as that imparted by retaining the murk during the fermentation. In Fig. 618, A is the press; B, the screw of iron; C, the *maye* or planks on which the grapes are placed; D, planks and blocks to support the grooved wheel on which the rope F runs; E, the cask to receive the must; G, the capstan that turns the wheel and its screw.

Fig. 619.



The great press, which will make from twenty to thirty barrels of wine in four or five hours, was, in the last century, constructed in the following mode—Fig. 619—and is the most common of the older kind. A A, the base and supporters; C C, the cheeks; D D, great beams of timber, sometimes four or six in number; E, the screw; F, the nut; G, the wheel turned by five or six men, holding the upright shaft; H, the cage, a square of timber lined with masonry, ten feet long and four and a half square on each side; I, the *maye* or platform on which the grapes are placed, as in the small press, with blocks and planks over them; L, a grooved channel by which the wine runs into the vat K. The cage will rise or sink into the pit; it is here shown ascending, and is in weight a couple of tons. Suspended at the end of the lever by means of its conjunction with the screw, it possesses immense power, increased according to the length of the lever, and thus it rapidly effects its object.

In some parts of the East the grapes are not pressed at all, but are beaten with wooden mallets on an inclined plane of marble, with a gutter at the bottom, which conveys the must into the cask or other receptacle.

On the sublimation of wines by the alembic, now the *still*, to which in recent times the term of distillation is applied, alcohol is separated. The name of this substance is derived from *a el*, more commonly *al*, the mark of the dative case in the Arabic language, joined to the word *coholmo*—in Spanish shortened to *colmo*—to *rise to the top* of anything; the invention having been brought into Spain by the Arabs.

Hence, too, the word *alembic—alambique.* The meaning of the original name was retained in the verb to *sublimate*, *sublime*, or *raise up*, to the head of the chemical vessel or retort. Whether this substance was first sublimated or distilled from the must of the grape, or being of eastern origin, from the fruit of the date, or what other fruit, is uncertain; but in wine it is an important natural constituent. Distilled from the grape, it exhibits a superiority over that from every other substance, existing as it does in a variety of vegetal productions. The mode in which alcohol is formed or evolved by the natural process in the fermentation of the must of the grape, it is necessary to explain; its disengagement from other substances by the still having been already detailed under ALCOHOL.

The preparations for fermenting the must by which alcohol is formed, and the process of wine-making completed, are made with great care on the eve of the vintage. In France where the art is most perfect from superior science, the vats are in some places rubbed with over-ripe Portugal quinces; over those of stone elsewhere, a thin coating of whitewash is passed, to saturate the malic acid in the must. Instead of lime, the wooden vats are by some washed with warm water, and afterwards a little brandy is passed over the staves, while others rub them with decoctions of aromatic plants, salt water, or boiling must. These methods are all beneficial, except the use of the lime, which, without great care and judgment, is apt to detach itself and communicate a bad taste to the must, which is deposited in the vat at once from the receptacles at the press, with or without the murk according to the views of the maker.

The whole of the must being in the vat, the fermentation is the next and most important part of the process. It is divided into two stages; the first rapid, sensible, and tumultuous; the second slow, and of considerable duration. The second is often denominated insensible, though sometimes the escape of the carbonic gas is perceptible to the ear in close-covered vessels. The first demands the access of air to proceed promptly through its regular course, which, although rapid, has always a slight progression to the end of the operation, which is at once discoverable by its being no longer turbid, and by the subsidence or depression of the head or *chapeau*—as the French denominate the scum, stems, and other substances, which float and form a crust upon the surface of the must, or rather of the wine, into which it has now become changed by the fermentative process—and the conversion of the sugar or glucose into alcohol. The reader will find the particulars of glucose described under STARCH and SUGAR, page 000.

One equivalent of anhydrous grape sugar is resolvable into four of carbonic acid and two of alcohol, whence this deduction :—

$$1 \text{ Eq. sugar, } C_{12},\ H_{12},\ O_{12},\left\{\begin{array}{llll} \text{4 carbonic acid,} & C_4, & H_0 & O_8, \\ \text{2 alcohol.......} & C_8, & H_{12}, & O_4, \\ & \overline{12} & \overline{12} & \overline{12} \end{array}\right.$$

Sugar of starch and sugar of milk may be converted into sugar of grapes. In the sugar of the cane, and in that of grapes, oxygen and hydrogen are found in the same proportions as water. Grape-sugar, found also in honey and in most fruits, is the slowest of all sugars to undergo fermentation, during which the sugar is resolved as above into alcohol and carbonic acid by the presence, in only a slight degree, of a substance tending to set it in action. This substance results from the nitrogenous constituents of the grape-juice, and is named *diastase*. In making all natural wines, this substance found in the must comes into action spontaneously. Yeast is the product of decomposed gluten. This yeast added to a solution of pure sugar disappears; but when mixed with juices which contain gluten as well as sugar, it is reproduced by the decomposition of the sugar. Gluten is present in the wine-must undecomposed; decomposed in the state of yeast, it would ruin the flavor of the wine, and should never be used to ferment either grape or domestic wines.

The immediate presence of the fermenting agent at once causes chemical decomposition. Oxygen and hydrogen exist in grape-sugar in the same proportion as they are found in water. Carbonic gas is given out; and in consequence alcohol is formed from the sugar, while water is decomposed during the putrefaction of the gluten. A temperature of 65° is most congenial to vinous fermentation, during which the heat increases. At 60° the fermentation is perceptible, but exceedingly languid. There are instances where it has been known to rise as high as 97° or 98°. Thus the fermentation in warm weather is found to be considerably accelerated. When the weather is cold, boiling must has sometimes been thrown into the vat, and red hot-iron bars have been plunged into the must with the same object.

Fermentation in a very small active mass will communicate the principle to a large quantity at rest. The magnitude of the volume submitted to the operation shows, too, that large quantities proceed more satisfactorily than small, though, in the latter case, the alcoholic strength and aroma are better preserved. After the lowering or fall of the crust or head, the sign of the first fermentation being over, the must is covered up from the air; no more opening being left than is sufficient to suffer the carbonic gas to make its escape.

But there are other substances formed in wine besides those already mentioned—some of which amount to little more than perceptible traces, and these are not found in all wines. Their quantity and even presence will depend upon the nature of the soil in which the vine was grown which produced them, and the cold or heat of the season; for in cold summers the fruit is acid. Starch, gum, albumen, gluten, extractive or coloring matter, bitartrate of potassa, malic, tannic, gallic, and a little citric acid, traces of tartrate of lime, of alumina, and potassa, sulphate of potassa, chlorides of sodium and of potassium, and in some, perhaps traceable in all wines, there are racemates and paratartrates. Racemic or paratartaric acid was discovered by M. KESTNER, and mistaken by him for oxalic acid. It is a modification of tartaric acid, and distinct in its nature. It was first thought to be peculiar to the grapes of the Vosges, and was called *acide de Vosges*. This acid is obtained from a solution, containing as well tartaric acid. The crystals are an oblique prism, with a rhomboid base; those of tartaric acid have a rectangular base. Its formula, as given by GREGORY, is $2\ HO,\ C_8\ H_6\ O_{12}$.

There is also an odorous principle called oil of wine, which is sweet, quite neutral, and is formed during fermentation, and obtainable from alcohol by pouring two and a half parts of sulphuric acid on one part of anhydrous alcohol. It boils at 536°, and has a specific weight of 1·133. It has a flavor somewhat resembling peppermint, and imparts a vinous smell to the wine newly formed. The salts procured from this oil are identical with the sulphovinates procured from sulphuric acid and alcohol. There is also a lighter species of oil of wine, specific gravity = 0·917 to 0·920, resembling olive oil. It is composed of $C_{16}\ H_{15}$, or very nearly the proportions of olefiant gas.

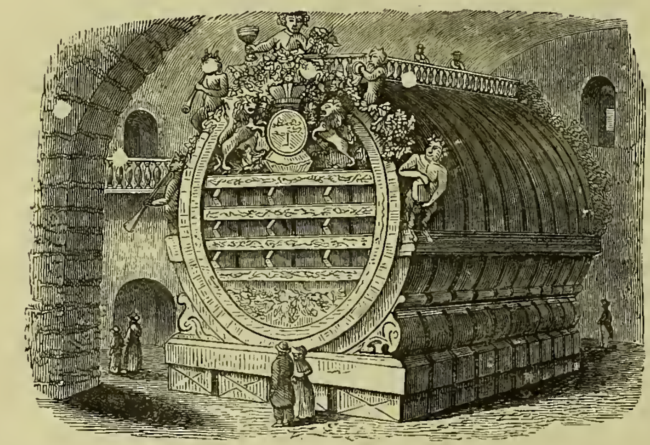
Climate makes an important difference in the component parts of the wine-must, as well in the acid as in the sugar dissolved. Hot climates produce a must rich in sugar; but this difference does not appear to affect the extent of the nitrogenous matter in the must, for it seems to be all expended in some wines before the sugar is converted into alcohol; and a part remaining undecomposed, it produces the thick sweet wines of the South. In colder regions the nitrogenous matter and sugar being alike expended, and the wine as it were balanced in regard to these principles, as in some German wines, dry long-enduring wines are produced. When the gluten is in excess, the wine, not preservable with facility, is soon converted into acetic acid if great care be not taken. It absorbs oxygen, and the oxidation is communicated to the alcohol. This oxidation may be prevented, and the conversion into acetic acid arrested, by the addition of a small quantity of sulphuric acid. Fermentation has been ascribed to the growth of fungi and infusoria; but much more evidence must be given before this can be received as a fact.

To return to practical vinification—the method of treating the produce of the vine in fermentation differs with the climate, season, nature of the fruit, temperature of the vineyard, soil, mode of culture and fancy of the proprietor, who is often guided by local custom. In some places the wine is not suffered to remain in the vat more than from thirty-six to forty hours. Near Lyons in France, it remains six or eight days, and in general from ten to twelve. In the South-west of France, it remains from twenty-five to forty; and at Narbonne, it is carried up to seventy days. When the farmer is asked how, the fermentation being over and the wine at the temperature of the atmosphere, he suffers it to remain still in contact with the stalks and stems to clear itself in the vat; he replies, It is the custom, and, if warned again of acidity through the breakage of the scum or crust, he answers he only acts according to usage—it should be *ignorance*. It is true the crust is almost always compact; but it is a hazard unless the saccharine principle be abundant, and the albuminous matter all taken up.

Vinous fermentation in general takes place under the free admission of air. An attempt was made by a Madame GERVAIS of Montpellier at the close of the last century, to introduce fermentation in close vessels. The idea was not new. M. DE LA PLOMBANIE, M. PORTA, a Neapolitan, and the German chemist, BECKER, at the commencement of the seventeenth century, had recommended the same process. But the admission of the atmospheric air is indispensable to the operation. A considerable noise was made about the invention, which, it was supposed, would preserve the aroma, and prevent the escape of alcohol. M. DELAVEAU instituted some experiments with great care under a fermentation for nineteen days, when it was found that the return from the vat had the most agreeable flavor; that the wine distilled afforded a spirit only equal to that fermented the usual way; the latter if anything yielding the largest quantity of alcohol. The vat with the invention gave sixteen and a half alcohol at a temperature of 80°·5; the vat with a simple cover, generally used in the South, sixteen and three-eighths; and that not covered at all, sixteen and an eighth. It was thought that the color of the red wines was somewhat deepened by the invention; but neither the aroma nor the vinosity was increased, nor was the invention considered of moment, so as to come into general adoption. Long experience had proved the efficacy of the old mode, and chemistry could find no ground to impugn it in a scientific sense. The strength of the wine, besides that which may be denominated alcohol, or rather its endurance, is in some degree due to the stems and the tannin it contains; but though used in port and some similar second-class red wines, they are excluded from the delicate red wines of France, though adopted in some of the white, while they are also excluded from the Rhine wines. In Spain the wine, having in Andalusia a great enduring power, is left to ferment in the butts, into which it is taken in the *mosto* or must state. The bungs are left open, and the wine and froth thrown up in the fermentation are poured back into the barrel *to feed* the wine, as they phrase it. This causes a renewal of the fermentation at every atmospherical change, and even on any accidental motion of the cask. In the month of March after the vintage, for the first time, the wine is racked. The advantage of large vats has made no way with the Spaniards. It might be best, *quien sabe*, but he keeps to the old track. The delicate and choice French wines would be ruined by such a mode of conducting the fermentative process.

On the Rhine the fermentation, after the must is ready made from picked fruit, the stalks put aside, and the different pressings set apart, takes place in casks, to preserve the aroma. The wine is then repeatedly racked, and placed in tuns holding about eight hogsheads and a half, where it remains for many years to acquire perfection. Some of the older tuns, in which the wine no doubt mellows best, are those locally denominated *fuders*, and will contain three hundred and fifty tuns. The celebrated tun of Heidelberg has long been renowned. It is thirty-one feet long by twenty-one high, and holds one hundred and fifty fuders, or six hundred hogsheads. It was built at Heidelberg in 1663, as a successor to one which held only a hundred and thirty-two. There was once a larger tun at Dresden, shown in Fig. 620, which held three thousand seven hundred and nine hogsheads.

Fig. 620.



It will be interesting to the reader to know the strength of the must at different periods. The specific gravity of the Pedro Ximenes must at San Lucar, after two days' exposure to the sun in September, was 1·092. At Paxarete in October, its must, after four days' exposure, was 1·121. The must of the Mantuo-Castillan grape at San Lucar in September was 1·069. The black mollat grape at San Lucar gave a must in the middle of September of 1·064; and at Paxarete, the last day of the same month, 1·089. At Chipiona, in the middle of September, the muscatel called gordo-blanco, a large white variety, after three days' exposure to the sun, gave 1·089; at the end of the month 1·096; and in October a specific gravity of 1·114. At San Lucar, in the middle of September, the white Temprana grape gave about 1·075; but, on three days' exposure to the sun, the specific gravity was 1·114. This last grape at San Lucar is cultivated to the extent of nineteen-twentieths of the vine lands. In the Paxarete, Ximenes, Muscat, and Tintilla wines, it enters largely.

In Hungary are made the celebrated rich liqueur wines *Essences*, *Ausbruchs*, and *Maslas*, *vins cuits*, and wines suppressed in fermentation mingled with other substances, and so long noted for their excellence; the grapes are carried in sacks, for the making, as those of Szamorodny, for example. They are treated in fermentation in the ordinary manner. The fruit or the essence, already obtained without pressure, and over-ripe, is carefully picked upon a large table, called a sorting-table, and placed in a cool vessel covered over. It is then put into a large vat, where men with cleanly washed feet, under a superintendent, tread them into a paste. This grape paste is then placed in a second vat, and covered over. New must of the common wine of the country is then poured upon it, the quantity of which used determines the quality of the wine, or wine *de liqueur*, according to the owner's pleasure. Sometimes two measures, or four, five, or six of the essence are added to ten of the common wine. The proportion of six to ten is rarely exceeded. The wine and paste are then mixed, and left for a couple of days, or for three, if the temperature be low, stirring the mass frequently. This thick must is then conveyed to the press, a slight pressure producing the richest kind; it is next conveyed into a cask, and thus becomes the celebrated Tokay Ausbruch, or flowing syrup. It is skimmed while fermenting, and strained into casks. It has a fine aroma, but never becomes very bright. It is soft and oily on the palate. There are two species, one containing generally sixty-one parts of essence, and eighty-five of wine; and the other called maslas, having sixty-one parts of essence to a hundred and sixty-nine of wine. The best sells for twelve pounds sterling the dozen. The fermenting and purifying proceed together. That of 1811 was celebrated, the fermentation having been perfect. There is besides a great variety of wine in Hungary, but all of a peculiar character.

The greatest care in manipulation, and the most scientific methods in the treatment of wine, have been tried in France, and the result has been the production of the finest wines in the world. The removal of the wine from the vat to the cask is there as carefully regarded as the work of fermentation. The casks are all made ready at the same time as the vats. If the wood of which they are made is new, they will not fail to communicate an astringency and bitterness to the wine. To prevent this, the casks are repeatedly washed with cold water, and then with hot, in which peach leaves and salt are infused. They are repeatedly shaken while the fluid is hot, and then are left so that the wood may absorb them, and they may penetrate into the pores of the timber. The casks are now emptied, and boiling hot must, to the extent of two or three quarts, is introduced. The bungs are put in, the casks shaken, and then left to cool. Some use only hot wine in place of the above substances. If the casks are old, they scrape off the tartar that lines the staves, and wash them with hot water and must, or wine. If they have contracted an ill smell, or show the least mark of decay, they are burned at once, because, in spite of all that can be done, sooner or later the bad effects will appear. Casks should be sulphured, if the least suspicion attach to them, by the introduction of a match at the bung. Such casks are generally made of oak staves, but some prefer beech. They bear different names in different parts of France, as *barrique* at Bordeaux, *botte* at Lyons, *tun*, and *pipe*, *et cetera*, in other places. When large, they are called *muids*, and very large ones *foudres*. Some have proposed vases of clay varnished, but they are considered porous, and cannot be easily conveyed from place to place.

The wine being fermented, the duration of the fermentation, depending upon the state of the temperature, the amount of sugar and similar things, to be decided upon observation and according to the season, the wine is drawn off into the cask. Some of the finest Burgundies, called wines *de primeur*, only remain in the vat from six to ten hours. The rest in the vat is only important on account of the color. If the skins were sufficiently broken, so that the coloring principle stands in no need of the action caused by the tumultuous fermentation to bring it out, the fermentation with the fruit and its grains being often more mischievous than useful, it is omitted. If the skins are sufficiently bruised and torn, when the fruit is trodden, to give out all the coloring matter, it is not considered wise to suffer the must to enter the vat after pressing.

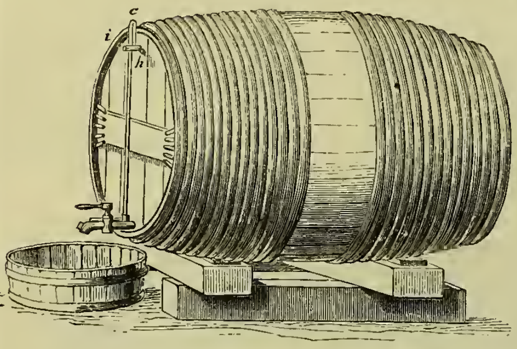
The drawing off the wine into the cask at the exact moment is a point of great importance. The crust or chapeau having fallen, and active fermentation ceased to the eye, all being perfectly quiet, the examination with a wine glass, the taste, color, and odor, except tested by experience, are often fallacious. Taste and smell are so different in individuals that there is much uncertainty upon the time when it is best to operate. The heat generated in fermentation depends mainly upon the quantity of glucose or grape sugar which has entered into the spirituous state. No fixed rule exists. It is frequently found that the maximum of heat is attained after twenty-one hours of fermentation in one case, and in another after ten, while the wine is not really perfected perhaps for twenty hours longer, so that the thermometer is no reliable guide as to the vinification. Something to determine the fact of the vinification mechanically, was long considered a desideratum by the French producers. There were the differences of climate, soil, and species of fruit to be considered. An attempt was made to ascertain this point by means of a vertical rod, marked with a scale to show the elevation and depression of the fluid. It was placed in the middle of the vat to indicate the depression of the must after its previous repulsion by the fluid, and that the time thus indicated should be that of drawing off the wine from the vat. This was found to be correct in seasons when the sugar was abundant, and then the moment of the retrogradation of the must was the best for emptying the vat. In wet seasons, on the other hand, the indicator did not seem to answer, but the inventor had little doubt of success in establishing a scale to indicate the time sought in different seasons when the temperature varied; but he was unable to carry out his experiments beyond three seasons, having been compelled to become an exile.

In drawing off the vat it is necessary, before commencing, to take away with great care, by the use of a wooden shovel, that part of the head or crust which, having contracted acidity by exposure to the air, if it broke and became mingled with the must beneath would spoil the whole mass. The must drawn off, the murk remaining in the vat is pressed for the wine called that *of the press*, which is equal in quality to that which has been drawn from the vat without pressure. The wines thus made are called that of the first, second, and third vatting, as before stated. The first taken is the most spirituous, and the last the harshest, sharpest, and deepest-colored. The second pressing holds a middle quality. The residue of the murk is used for the manufacture of verdigris, for the food of cattle, for vine-dressing, or for nourishing pigeons, which greedily devour it. These later wines of the press are sometimes mingled with that of the vat, an indefensible practice, because the wine from the vat will often by such a mixture lose its own peculiar delicacy.

The wine being in cask is, in the pure wine countries, directly placed in the cellar. The cellars vary in different countries. In Spain those of the Xeres district are of great size, to the extent of three hundred English feet long by above two hundred broad. Four thousand casks of wine are arranged in similar cellars in tiers, and are called *soleras*. The wines of different seasons are mingled in these, so that one will contain some of each vintage for thirty seasons. The wine is fermented in the butts, the bung-holes being left open without endangering the wine; nor is the cellar temperature much regarded, such is the firmness of the wine. In Valladolid the cellars are deep in the earth, like mines, with huts over them. In France the cellar is an object of peculiar care, the exquisitely delicate wines of the first-class in that country demanding great attention as to safe-keeping in their highest and most perfect state. The best and favorite cellars are held to be such as are situated under uninhabited buildings, as is observable in the places most noted for the culture of the vine, having a Northern exposure, and fifty or sixty feet deep, according to the dryness or the humidity of the soil. A uniform degree of moderate humidity is best. A cellar too damp causes the decay of the barrel staves, or covers them with a mouldiness which communicates a bad taste to the wine. If a cellar be too dry it makes the staves of the casks shrink, and the wine is wasted by leakage. The air should be admitted only by small openings, facing the North, made near the roof or vault, and susceptible of being closed when the weather is too hot or too cold. The vault or roof should be as solid and thick as possible, in order that no external concussions should be communicated to the wine. The soil above the vaulted roof should be united and well beaten down, and that part designed to receive the bottled wine should be covered with sand or fine fresh-water gravel.

The casks should be placed in a position perfectly horizontal, upon wooden beams six or seven inches square, supported by others transverse. Wedges should be forced under the casks on each side to keep them steady, and neither the casks nor their supports should touch the wall of the cellar. If the casks are not set perfectly level, the wine lees will collect in the back part and prevent the wine flowing clear out of the cask the usual way. If the front be too much raised, the lees will come to it when the cask is elevated behind, in order to draw off the last of the wine, and thus stop the passage. The lees should settle in the belly or hollow of the staves, which will take place when the casks are kept perfectly horizontal with wedges, as shown in Fig. 621. Attached to the cask here given is an air tube, to illustrate the mode adopted in some parts of France to prevent the admission of air over the wine, so apt to cause acidity.

Fig. 621.

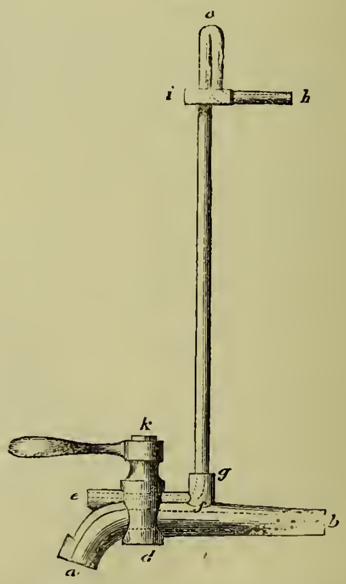


The tube or canal, *a b c*, is of the common form, except that the bottom of the tap at *d* is pierced with two apertures, of which the lower serves for the passage of the liquor, and the other corresponds with tube *e f g c h*, by which air is introduced into the tube to replace the liquid drawn out. The result is that it suffices to turn the tap, *k*, to cause the liquid to run; and to shut it, that all communication with the exterior air shall be cut off. It is evident that when the tap is turned the wine will run out, and that the exterior air will replace that wanting by the tube *e f g c h*, and that on shutting, *k*, the pressure of the air will cease with the running of the wine. The tube is carried higher than is necessary, that the wine may not enter the tube at *h*, and may have the least possible distance to the surface of the wine, and thus prevent agitation. The tube at *h*, and the tap at *b*, both enter the cask. When the cask is to be all drawn off at once, of course such an application is superfluous, but it is invaluable where small quantities are taken in draft.

No garden stuff, green wood, flowers, fruits, or similar substances must be permitted in any cellar in which wine is kept, because the gas disengaged from them promotes acescency. The wine being deposited in the cellar, the insensible fermentation commences but too sensibly if that in the vat was imperfect. Carbonic acid gas still makes its escape, augmenting the volume of the wine, and forcing itself out at the bung in froth or scum. Hence it is necessary to take care that the casks are not quite filled when they leave the vat. At least two inches' space is left, and the bung driven home to prevent the slightest entrance of the atmospheric air. A gimlet hole is made on the upper side of the cask, and stopped with a peg or *fausset*, in order to let the carbonic gas escape. Some wine-makers place in the bunghole a linen cloth, filled or covered with sand or vine leaves pressed down with a tile.

When this fermentation ceases, and the wine has sunk down, the cask must be filled up and hermetically closed with linen round the bung. The operation of filling up by the bung is denominated *ullage*. In some places ullage is performed every day for the first month, every five days for the second, and every eight until the wine is racked. The celebrated Hermitage wine is thus treated. At Bordeaux ullage is performed on the eighth day—filling up exactly every ten days during the first month, and then once a month to the time of racking. In other places, if the cellars are dry, twice in two months; if humid, every three months. Ullage is performed in fine weather with wine fully equal in quality to that in the cask. The cellars are to be visited daily to guard against accidents, such as a leak in a stave from a wormhole, injury from commotion in carriage, mouldiness of the staves if the cellar be too damp, or shrinking of the staves or heads in those which are too dry. The wine from time to time is tasted, to ascertain its state and remedy any perceptible mischief. When ullage is neglected, a white mouldiness, called the *Flower*, is observed on the surface of the wine—a certain forerunner of acetous degeneration. The air is at once forced out, the nozzle of a bellows being introduced for that purpose, and then it is agitated. A sulphur match is introduced, and the bung inserted. The cask is struck from below, to raise any concealed air bubbles to the surface, and to carry all the mouldiness possible to the bunghole, which is filled so as to make the wine run over, and these efforts are continued until no vestige of the Flower appears. The wine in the cellar is observed to work much when the vine commences to bud, and when the fruit ripens.

Fig. 622.



which **BUFFON** attributes to the changes in the juice of the vine. **FABBRONI** and other authorities have stated that this phenomenon is only observable when the particles of the wine have not been separated by a sufficient quantity of alcohol—in other words, when the glucose was not equal to the subjugation of the gluten, and the other constituents were not in due proportion. This fermentation is prevented by the use of sulphuric acid, sulphate of lime, mercurial oxides, additional alcohol, camphor, ice, and water at the boiling point. When the wine is still, it is perfected, and only deposits its lees, consisting of portions of the pulp of the fruit, of the coloring matter, and of the tartar, which last is found crystallized on the interior of the staves of the cask.

The next process is that of racking, undertaken to clear the wine of the substances which tend, by mixing anew with the wine, to form a fermentation. It is an operation not generally performed at a stated time. In some places it is done in December, after the vintage, when the wine is required to be moved; if not, it is done annually, generally in the months of February or March. In some countries this operation is performed twice the first year, in spring and at the end of September; in others, at the end of December and middle of May—the first during a sharp frost. Much, however, depends upon the quality of the wine. Generous wines may rest upon the lees three or four months, and be only racked once in two years, but in general they are separated from their lees before the first equinox of the spring succeeding the vintage. There are times when, on the other hand, in lieu of racking, it becomes necessary to recombine the lees with the wine, in order to establish a fermentation which may ameliorate them and promote their maturity. This operation being of importance, it is necessary to describe. The smallest inadvertence will produce, in conducting it, the acetic action, the tendency to which, the moment it is perceived, must be met by racking at once, and moving it to the coldest place possible, and before racking it must be fined. The weather most proper is that which is dry and clear.

The wine is drawn off carefully that it be not disturbed, and when the cask is stouped for the last of the liquor, it must be done with great care and judgment by hands accustomed to the operation. The Beaune wines in France are generally racked by the introduction of an instrument into the cask well calculated to draw off the fluid without disturbance, and these wines are always remarkably fine. At Condrieu on the Rhone, the wine is racked eight days after it is made, and before the end of the month it is fined, then racked anew, sometimes twice or thrice at an interval of fifteen or twenty days, in order to procure the limpidity so desirable. Wines not cleared sufficiently by racking are fined, the substances used for the purpose being isinglass and whites of eggs. The isinglass is cut up and steeped in a little wine, until it becomes viscid and softened. It is then thrown into the cask. The wine is afterwards strongly agitated. The quantity of finings used is about five drachms to every five or six hundred litres or quarts of wine. The whites of eggs, preferred in some places, are well beaten up in a little wine, poured into the cask, and left to rest for ten or fifteen days, when the wine is racked during the first Northerly wind. From six to ten fresh eggs are used for every twenty-two gallons imperial. Various substances have been applied for the purpose, as gum-arabic, hartshorn, calcined flint, rice, milk, and starch, but none produce the desired effect so promptly as isinglass or the white of the egg. Ordinary wines lose their acidity by fining, and the finer classes increase their brilliancy and clearness.

Wine is sulphured at times, in other words, impregnated with sulphurous gas, by burning sulphur matches over it. These consist of a roll of linen or cotton an inch and a half broad, and six or seven long, dipped in melted sulphur, to which powdered leaves of aromatic plants are sometimes added. Those made at Strasburg are noted. The match is suspended from the bunghole by a wire, and being lighted, the bung is closed. The air within dilates and escapes through the smallest opening. The operation contributes greatly to the preservation of the wine, though some say it injures the color of red wines. Those who object to it throw a little brandy into the cask, to which they set fire with a bit of lighted string, and while it is burning close up the bung, leaving only just air enough to keep up combustion. In other cases a wine is made; the fermentation is arrested, and the must placed in a cask until it is a quarter filled, and a number of sulphur matches are burned over it. The cask is then closed and strongly agitated, until no gas escapes on opening the bung. More must is then added, and the agitation repeated, until the cask is full. This must never ferments, has a sweet taste, smells strongly of sulphur, and when a certain quantity of alcohol—of the strength *trois-six*—is added, a wine named *wine of Calabria* is the product, employed principally to give strength and sweetness to wines deficient in those qualities.

MULDER states that wine, stored in wooden casks, loses water, whether mixed with alcohol or not. But if evaporation affects the contents of the cask, the loss must be repaired, otherwise the action of the air would turn the wine acerb, and convert the alcohol into acetic acid. It is chiefly water which is evaporated, and its loss is made up by adding wine. All the constituents of wine, with the exception of water, are hereby increased, and the wine becomes not only stronger, but better flavored. The vinous components being more concentrated, are better able to act chemically upon each other, and this, *per se*, would account for the improvement of the wine. Here one has a general statement of the causes upon which the difference between new wine and that which has been stored in casks mainly depends. But the change is carried still further. The concentration of the wine, or rather the diminution of water, which is continually replaced by wine, causes a constant augmentation of tartaric acid in the wine. Wines which are poor in sugar may easily become too sour, and all wines cannot, therefore, undergo this process. The quantity of tartar in the wine is not increased; for, being insoluble in alcohol, the continual increase of alcohol precipitates it. That which is augmented is tartaric acid, which is soluble in alcohol, and insoluble in cream of tartar.

Madeira, and such like wines, are sent to warm countries to improve. **MULDER** had Madeira which had been seven times in cask to the East Indies and back, *and truly*, says he, *such nectar was unknown to the gods of the ancients.* The drier the atmosphere is which surrounds the casks, the greater will be the evaporation. To avoid this, care must be taken to prevent draughts, and to keep the air of the wine stores or cellars moist.

Wines remain in wood different periods, according to their qualities, and while thus resting are in a state of improvement. Some repose only three or four years before bottling. Tender, delicate, light wines gain little in the bottle, while strong spirituous ones preserve well in that state, and to a certain point improve. In bottling fine wines the bottles and corks should be new; the smallest defect in the latter determining their rejection. The French dip the corks and the bottle necks in a composition differently colored, to distinguish the wine, and thus shield the external part of the cork and a little of the neck of the bottle with it from the action of the air. This composition is made for three hundred bottles with two pounds nine ounces of rosin, half that quantity of Burgundy pitch, a fourth of yellow wax, and a small quantity of red mastic melted together, so as to form a liquid mass in which the corked necks of the bottles are dipped. In the cellar the bottles should be placed horizontally, to keep the corks always wet. Fine fresh-water gravel or sand is their best bed, and keeps the wine cool, but sea-sand from the salt in it, is pernicious. Sawdust only answers for coarse wines.

Wines of fine quality can only be mixed with others of a like quality to render them more generous, or to have a larger quantity of one particular flavor. It is a robbery or a great abuse to sell wine mixed in any other way for a genuine growth. Wines of Bordeaux are sometimes strengthened with hermitage or wine of Cahors, and are known as Medoc wines; but they are genuine and of good quality. Wines are liable to alteration and to degenerate. Such are loss of color, bitterness, acidity, tasting of old, of the wood, of musk, mouldiness, and what the French call *graise*, milkiness or cloudiness. To amend the last they use pure tartaric acid, taking care that little of the carbonic gas given out shall escape from the cask. This acid is composed of 2 HO, C_8 H_4 O_{10} and is found in a good many fruits beside the grape. The acid is mingled with sugar and introduced hot into the cask, which is closed and agitated for five or six minutes. Two days after, the wine is fined in the ordinary way. The carbonic gas is the agent of the cure. Wine is sometimes passed over fresh lees as a remedy for the same disease; and then racking is had recourse to afterwards. Acidity generally attacks wine which wants body. This never amends itself, but proceeds to the acetic state if left alone. Taken at the earliest moment, it is transferred into a cask impregnated with sulphur by the means before described; and different modes are employed for the cure of the mischief. Some dissolve honey, others liquorice, in the wine. Acetate of magnesia, bone gelatin, and similar substances are used; but the best mode of cure is to pass the wine over the relics in the vat, after the vintage product for the year has been drawn off. Even then it should be drank early, for it cannot be trusted over another season. Oftentimes the acetous fermentation has already commenced, and there is no resource but to leave it to the vinegar-manufacturer. The bitterness in wine will sometimes become cured by itself when in bottle. It takes place in old wine. If not cured by passing the wine over fresh lees or mingling new with that attacked, it should be reserved for the still. Loss of color generally happens to the deepest-tinctured wines approaching age, arising from a species of fermentation for which recourse is had to purified tartar reduced to a fine powder and mingled. If unsuccessful, it must be mixed with a younger growth. The taste of old and musk—the latter thought to be caused by insects—the depositions of different wines, and the taste of the wood, add to the multiform cares of the wine-grower and admit of a variety of applications for cures not always successful. There is a wide road here for chemical investigation and experiment yet untrodden, as there is also to determine exactly those constituents which give to certain wines their delicate aroma and flavor. The odor which is peculiar to all wines must, to a certain extent, be ascribed to enanthic ether.—*Vide* ALCOHOL, vol. i., page 105.—The volatile substance existing in wine, which imparts to it, conjointly with enanthic ether, its vinous fragrancy, is alcohol. Other beautiful volatile compounds have been detected in wine, but there is much yet to be discovered. To what substance does a fine Sauterne owe its most peculiar but magnificent bouquet? Acetic ether appears in most, perhaps in all, aromatic wines, and is developed in them by time. The adulterators of wine are well acquainted with this fact, and know how to make use of it. Acetic ether is largely sold for this purpose, and added in proportionably small quantities to wines which are not aromatic, to improve their fragrancy. Two or three drops are ample for a bottle of wine. The reader is here referred to the article ETHER, vol. i., page 832, for full particulars with regard to the properties, *et cetera*, of the delicate ether existing in wine and spirits.

Besides the wines denominated sweet and dry, prepared from the fruit in the mode, and their difference arising from causes already stated, there are prepared wines in which the must is concentrated by evaporating a portion of the aqueous part, a very ancient custom wherever wine of the usual kind is made, called in France *vins cuits*, in Italy *vino cotto*, and in Spain, from the Arabic, *arropé*. The wine is boiled down to a third part, being skimmed of its froth, and sometimes, while boiling, aromatic substances are infused, or else it is used in its unperfumed state for strengthening other wines.

Dry and sweet wines, or wines of *liqueur*, are distinguished principally by the saccharine principle, in sweet wine, not being all converted into alcohol, the glucose surpassing the gluten in proportion, and the change being in consequence only partially effected. Such are the wines of Malaga, Rivesaltes, and Frontignan, and the wines from the rich muscatel grape more especially. Straw wines are also sweet wines, made of grapes for some months suspended upon straw bands and afterwards pressed and fermented. The produce is about a sixth only of that obtained at the vintage. It has a strong rich flavor of the dried raisin. There is also a wine called *de Grenier* in France, made in nearly the same manner, and a sweet white styled *de Garde.*

Another wine of a very distinct character and of two kinds, one drier than the other, is procured by suppressing the fermentation, in other words, retaining the carbonic gas to a considerable extent. This species comprehends the wines of Champagne and their unworthy imitations, called sparkling Burgundies, Moselles, and others, all managed in the same mode. There is a genuine wine at Arbois of the same kind, or *mousseaux*, as the French term it, made in a mode somewhat different. The crust or chapeau is allowed to rise and settle over the must, as in the common mode of fermentation, so far as that the fermentation is not visible and no further, in order that the wine may be racked off in a clear state, being watched day and night for the period when bubbles of carbonic gas begin to appear on the surface. It is then racked into a vat and remains until a second crust or scum forms, and this is repeated until the wine is perfectly limpid. It is now placed in casks carefully kept filled. The bungs are daily examined in case of starting, that the cask may be filled up immediately. The air is excluded when the fermentation ceases, racked again in January or the following month, and in March fined and bottled. The corks being wired, the wine is deposited in a cellar of the requisite temperature.

To return to the more celebrated wines of Champagne, distinguished as still, creaming, and sparkling wines, or *mousseaux*, *crêmans*, and *non-mousseaux*, of which the two last are most in esteem. The best froth very slightly, as Sillery; and the finest, called *vin du roi*, not at all. These wines come from the banks of the Marne and constitute a unique class. They are made for the most part of the blackest grapes, gathered with care, and only the sound fruit used. The grapes are carried to the press in baskets, covered up from the sun, and placed on the press with as little motion as possible. The must is poured into a vat for a term of from six to fifteen hours, that the dregs may be deposited. As soon as ever fermentation appears, the wine is transferred to the cask. The product of the first pressing is set aside as the choicest. The second pressing, or the wine of the *first cutting*, lightly colored and spirituous, partly composes the effervescing wines. The wine of the third pressing is kept for giving strength to the ordinary red wine of the country. This wine is put into bottles in March or April. At Rheims, on the other hand, they bottle the Sillery in January, although at the risk of its imbibing the effervescing quality. It having been thought advantageous to secure champagne of a uniform quality, which it was difficult to do from its being put into small casks; tuns holding twelve thousand litres were a few years ago introduced at Rheims by a German house, and the advantage of their use became evident.

The next step is to procure bottles of great strength, free of air bubbles, of the exact size, and without a flaw. The number required to bottle the effervescing wines in the department of the Marne is enormous; eight hundred and sixty-six thousand gallons having been bottled in one season in the arrondissement of Epernay alone. In March or April the bottling commences. If done earlier, the breakage would be greater, fifteen per cent. being the ordinary loss. In the fermentation the carbonic gas not being allowed to form sufficiently or fully develop itself in the cask, it is quickly reproduced in the bottle; the saccharine principle renews its progress towards alcohol; and if the latter be sufficient to prevent the decay of the wine, the quality is good. This wine does not effervesce in uniform times. Some kinds will do so in a fortnight; others will be months before the signs appear. One wine will require a change of temperature for the purpose, and must be brought up nearer to the surface of the ground, if the cellar be deep. Another kind will not exhibit itself until the month of August, and a third kind only at the time the owner's patience is almost exhausted, when it will appear unexpectedly. If a wine shows no sign the first year, it is mingled the next year with new wine known to possess the effervescing principle. Nothing is certain; the cellars, their soil and depth, the air-holes, the difference of the place of growth—all seem to have an inexplicable effect upon the operation.

The bottles, carefully cleaned by rinsing and shotting, are placed in the working shop or *atelier*. The barrel-heads are bored, and a small brass pipe with a gauze-strainer, is inserted. The bottles are filled so as to allow about two inches clear space between the cork and the wine. This space diminishes, while the carbonic gas is generating; and the fractured bottles show that the expansion of the fluid has primarily quite filled the void. A workman who fills the bottles passes them on the right hand side to the principal operator, who is seated upon a stool, with a little table before him covered with sheet-lead, and about as high as his knees. He inspects the allotted space between the cork and the wine, regulates it exactly, selects a cork, moistens it, introduces it into the bottle, and strikes it so hard two or three times with a wooden mallet, that an observer wonders it is not broken by the violence of the blows; and yet fracture this way is rare from the attention paid to the management of the bottle at the same moment. This workman then passes the corked bottle to his right, where a third workman, seated precisely in the same manner, crosses the cork with pack-thread, and ties it strongly. He then passes it to a fourth workman who wires the bottle, cuts the wire, and hands it to a youth who places the bottles upright in the form of a parallelogram, so that they can be counted in a moment. The daily labor is calculated at a drawing of from sixteen hundred to seventeen hundred bottles. The best cellars of Epernay are those of M. MOET, and the bottles run in a pile from end to end, six feet high, and are carried down in osier baskets, having in each twenty-five cases for the bottles. Two men carry them by leather belts drawn through the handles of the basket. Slopes are prepared beneath in cement to carry away the wine from the broken bottles in the piles, with reservoirs to collect it. The bottles are placed head to tail on laths, the corks one way the reverse of the other.

The piles are very solid; and any one of the bottles with the neck to the rear of the pile, can be easily withdrawn in order to examine its state, and see if the carbonic gas is developed. If not, all must be got into the proper state, cost what it may. When a bottle is drawn from a pile, and kept in a horizontal position, a deposition is generally observable called the *griffe*, or claw, from its branching appearance. Before a bottle breaks, the vacancy below the cork disappears by the expansion of the carbonic acid, which generally occurs in July or August, when commonly from four to ten per cent. of breakage is experienced; too often the mischief reaches from thirty to forty. Sometimes, of the same wine in the same part of the cellar, one pile will remain with the gas undeveloped, while the other shows no sign of effervescence. A current of air will sometimes make the wine effervesce furiously. Thus great expenses are incurred, not only by breakage, but in attempts to excite the carbonic development. The loss by the breakage is often not equal to that of correcting the inertness of the wine, independently of the trouble. If not exceeding ten per cent. in breakage, the maker is satisfied. If it is deemed necessary to take down the pile, the bottles are set upon their bottoms for a longer or shorter time, and this causes a difference in the quality of the wine. At one time it is removed into a deeper cellar; or, lastly, the bottles are uncorked to disengage the gas, and clear the space under the cork. When the carbonic gas is furious in its development, the wine is wasted in large quantities. The wine of the broken bottles becomes scattered among the sound, or fragments remain which contain wine, and become acid and even putrid. The gutters become infected, and in the air of the cellar new principles of fermentation ensue. In August workmen have been obliged, owing to the fragments of glass projected from the piles, to put on wire masks, and entering the cellar to throw cold water over the wine. The breakage ceases in the month of September. In October the piles are *lifted;* the bottles being taken down one by one, putting aside those broken, and placing on their bottoms those in which, on examining the necks, the corks and sealing seem to have moved. Some bottles are found to have lost a portion of their contents, and the loss must be repaired. The deposition, too, must be removed. For this purpose the bottles are placed in an inclined position of about 25°, and are shaken two or three times a day, to detach the sediment, for ten or fifteen days successively. Planks with holes in them receive three or four thousand bottles together, keeping them in the right slope. The workmen then, with considerable dexterity, get all the deposition into the neck of the bottle, near the cork, the wine being perfectly clear. Every bottle is then taken by the bottom, kept carefully reversed, and the wire and twine being broken—the bottle resting on the workman's knees—the cork is dextrously withdrawn, so as to permit the gas to explode, and carry the deposition with it. An index is then introduced into the neck to measure how high the wine should ascend, and the deficiency is made good with wine that has before undergone the operation. The bottle is then a second time corked and wired. If the wine remain long in the cellar afterwards, before it is sold, it is submitted to a second clearance or *degorgement* of a similar kind about a fortnight before it is sent away; the process to the last being laborious and expensive. These wines do not admit of being mingled with any but those of their own growth, and those genuine are rarely mingled at all. Grey champagne is made by treading the wine slightly before pressing, and rose-colored by a longer treading; but the latter is generally wine of inferior quality. In good cellars these wines will retain their excellence for twenty, and even as far as thirty years, in the last case imbibing only a slight degree of bitterness. The temperature of the cellars in which the wine is kept, is best at about 53° almost unvaryingly. The receptacles at Epernay are excavations in the calcareous rock, thirty-five feet below the surface of the ground. The creaming and still wines keep the best; those very frothy are most liable to change, and are really the least worthy of the class.

The finest red wines in the world are those of Burgundy, in the district called the Côte d'Or. They are produced principally from the grape called the Pineau. From twenty to thirty hours in the vat are sufficient to convert the glucose into alcohol, and then in two or three years they are fit for drinking. If moved in the cask in the least as they deposit, they are apt to spoil. On this account the finer kinds are only removed in bottle, and should be kept with great care. When old they take an amber color. In England the first classes of these wines and their proper management are unknown; the second classes alone being imported as the first, the coarse taste of the English palate in wine preventing the discovery of the difference. The finer wines are all produced in the districts of Nuits and Vosne; of these the Romanée-conti and the Chambertin are among the more celebrated. The white wines of the same district are not so well known or esteemed as the red. In the Mont Rachet wine, a celebrated growth, made near Beaune, occurs one of those extraordinary phenomena in wine which no scientific investigation has succeeded in explaining. Three kinds of wine are made of fruit grown on the same land, so contiguous as only to be separated by a footpath, having the same exposure, the soil appearing the same, as well as the species of vine; yet the last brings only one-third the price of the first. The whole ground is about thirty-seven hectares, of which the most prized is but seven, the next quality eighteen, and the third twelve. The wine of the first fruit sells at twelve hundred francs, the second six hundred, and the third four hundred.

The climate of Italy so congenial to the vine, produces no wines of export much valued, owing to the ill management of the vintage. No attention is paid to sorting the grapes; ripe and unripe are thrown into the vat together. Nicety and even cleanliness are neglected. The grapes are trodden and thrown into a vat, where the must remains fourteen days in a state of continued fermentation until the wine is spoiled. Sometimes the must is left exposed to the air for a month together, and the wine, ill-managed, has no reputation. In Tuscany more attention is paid to the process than in other parts of the country, and very palatable wine is made, but with little improvement in the process. The Montepulchiano is a sweet wine long noted there. This wine is racked repeatedly for two months after it is made, but the fermentation is often continued until the wine has begun to contract acidity before it is removed into the cask. In Naples they make a sweet wine called *lacryma Christi*, but the process is as careless as in other parts of Italy—in fact there are four or five wines of that name, some pretty good, others execrable. In Sicily the Mazzara wines, and the sweet wines of Syracuse, are made with little care; but English capital and some pains having been bestowed on the Marsala and Etna wines, they are exported to England, according to custom, brandied to excess to save care in their management, or, as the phrase is, to *fortify* them. The Marsala wine, well treated, is sound and good, and made in the fine climate of Sicily with French science, might still be greatly improved.

The Greek islands produce wine of various kinds, but mostly muscadines. In Cyprus the grapes are not suffered to lie too numerously on the stock. They are of a rich purple, with a thin skin. The vintage begins at the end of August. For the celebrated wine of the Commandery, the fruit is placed on covered floors called *punsi*, and spread out with care in a bed of eighteen inches thick, where the grapes remain until the seeds or grains are ready to drop from them. They are then carefully lifted with wooden shovels and carried to rooms paved with marble, or covered with a cement equally compact. These floors are made of a gentle slope. The grapes are bruised with a wooden mallet, and pressed in little presses denominated *patitisi;* the must, which is very thick, flowing into a vessel on the lower side of the floor. This vessel is emptied, when full, into small vases, and in these conveyed into baked earthen vessels with acute bases, like the ancient amphoræ. In these the wine is left forty days to ferment, in some places with the vat covered while in that state. This wine, if taken while in a state of fermentation, causes severe colic pains, to prevent which it is filtered through bags of vine ashes, but when thus treated it never attains the perfection desired. When the fermentation has ceased, the wine is shut up from the air with covers of baked earth, and has already put on a lighter color than before. These vessels are either coated internally with pitch, or varnished the instant they leave the potter's hand. If varnished, the composition consists of a boiling liquid in which turpentine and pitch are mingled with vine ashes, goat's hair, and fine sand; this effectually closes the pores, and never falls off. The art of making these vessels belongs to the remotest antiquity. They hold from twenty to thirty barrels each and in them the lees are deposited, which are called *mana*. When removed, leathern bags are adopted, pitched on the inside, and detrimental to the wine, which does not for many years lose the disagreeable flavor. The cellars, in so hot a climate as Cyprus, are all above the ground; little light is admitted, and the aspect disregarded. This famous wine was named from the Commander of the Knights Templars, to whom the district once belonged. The Commandery wine resembles the Italian wine of Chianti in color. From a red it changes to a yellowish hue the first year, fines itself as it grows old, and in nine or ten years takes nearly the same appearance as the sweet wines of the South of Europe. The dregs are thick, and supposed to aid the fining. When brought from the country to the town and put into casks, it is always in such as have lees remaining, in which it is left for a year. Whether ullage is attended to or not, it makes no difference in regard to the excellence of the wine, for sometimes a cask is left not three-fourths filled. It is sold at the vineyard by the load of sixteen jars, each containing five Florence bottles. The wine is warranted good by the seller until the August after the vintage. It is generally exported in casks of three hundred and fifty bottles each. Only about ten thousand jars are now produced. When poured into a glass, if good in quality, the particles adhere like oil to the sides. Cold injures it; in a Northern climate it must be placed before a fire. The lees are always treasured up, and are often in color a mixture of black, red, and yellow, though generally like Spanish snuff. Those wines and the muscadines of Cyprus are different. The wines of the Greek islands are mingled with rosin to impart durability, and are very disagreeable to the taste in consequence. The wine of the Crimea, at least that called *kokour*, is fermented coarser than in Cyprus. The vats in many places are only pits dug in the ground, plastered with a composition. The Shiraz wine of Persia is made of trodden grapes, fermented in jars of glazed pottery agitated briskly; it is then bottled for sale.

The wine of Portugal, forced upon the people of England in 1703, by rendering the duty on that wine a third less than on the produce of other countries, drove out many fine wines, of which there was a great variety before, and forced an inferior article upon the public, under the absurd idea that Portugal would take English woollens in return, as if all trades were not an exchange of goods. The effect was to drive all variety in wine out of the country, and make Englishmen take an inferior article. At first the wine came in its natural state, but was afterwards sophisticated and brandied. Efforts were too soon made to control the market by limiting the supply, and rendering the wine nearly of a uniform quality. After the Portugal wine monopoly of 1756 was established, brandy was added, and increased until, in recent times, no less than from twenty to twenty-four gallons per pipe are flung into the wine during and after fermentation. In its natural state this wine is not permitted to come to England. The growth is stinted because the export is limited by a privileged company, which creates an artificial scarcity. The wine is adulterated with a mixture called *geropiga*, two-thirds must, and one-third spirits 20° above proof, with elderberry juice and sweetening matter, and is sanctioned by the English Government, though a gross adulteration, being admitted here as a spirit to carry out a fraud. This medley is used only in preparing wines for England. The pure wine is seldom allowed to be exported, although good and enduring, since by this doctoring there is an equality of class established that defies seasons or bad crops. The grapes are gathered when mature almost to shrivelling. They are from the bastardo, sousao, and alvarelhao vines. The fruit is trodden with the stalks, and remains during the fermentation, which continues about seventy hours, in vats containing from ten to twenty pipes each, and while fermenting, brandy is added. The wine is racked in February, and sent to the company's or merchant's cellars in Oporto. More brandy is added to the wine intended for exportation, and again in a year, when shipped, more is thrown into a wine having in its natural state, on the average, amply sufficient alcohol to insure endurance with common care. It now carries a strong odor of brandy, and must remain a dozen years until the wine, or rather brandy-wine, is sufficiently subdued in alcohol to be drunk, when it bears little resemblance to the genuine wine, having become dull, and its freshness and aroma having disappeared. The consequence of the delay often is, that while ameliorating the extractive and coloring matter of the original, if not of the elderberry, becomes deposited, the wine tawny, and the flavor without a trace of the real unadulterated article. The perverseness of usage is become in a century so much in harmony, on the part of the consumer, with the merchant's notions of brandy being necessary to preserve a wine with sufficient alcohol by nature, that a genuine and honest port wine would now be regarded as worth little, on the plea of coldness, except to real connoisseurs. At first, in 1730, only about two gallons were added to a pipe. In 1754 the practice was styled *diabolical* of checking the fermentation in this mode of *fretting* in spirit, which it was fondly imagined immediately assimilated with the natural alcohol of the wine. The Portuguese charged the English at Oporto with commencing this base practice, and making wine seem *like liquid fire in the stomach.* It is observed by one authority that, in preparing these wines, it resembled throwing into one large vat all the red wines of a country of different growths, to produce an immense quantity of second-class wine. There are excellent wines thus mismanaged. The Collares port, Bucellas, Lisbon, and other wines made in the customary manner, bespeak that there is no fault except in the management. One wine-grower purchased elderberries a few years ago to the extent of four hundred pounds in a season; and one hundred and twenty pipes of adulterated must have in one year been landed in London from Oporto, to mingle with Portugal red wine in England, and doctor or strengthen what was too weak. Science can discover nothing worthy of record in the manipulation of the Oporto wines.

The vines of Madeira, now nearly destroyed by the *oïdium*, or wine disease, were a remarkably fine class, They were planted in a volcanic soil, a mixture of red and yellow tufa, called *saibro* and *pedro molle.* A light clayey earth and volcanic cinders were intermingled. The husbandry was rude; the vines planted in trellises. The vintage took place in September, and the wine of the highest quality, called *pingo*, was that which flowed from the treading alone. The wine was pressed to the fourth pressing in a trough-press, with a lever like that of a cider press. The grapes were sorted and the *mosto*, or must, fermented in pipes. Gypsum was sprinkled on the grapes. The must was agitated during the fermentation, which exceeded forty days in duration. The wine was mellowed in stoves, kept at a temperature of 80° or 90°. A voyage to the East or West Indies was always preferable for ripening the wine, when it could be accomplished. There was once a very agreeable cordial wine, made in Madeira, by checking the fermentation and adding brandy to the must. The *sercial* is the product of the hock grape, never drank under seven years old, and then not in perfection. There were once three kinds of malmsey, from as many different kinds of grapes, in these islands. That from the cadel grape was the best. The tinto resembled new Burgundy, but was less harsh; it was drank under three years old, at which age it lost its color, and took that of old Madeira. It had an agreeable aroma. Wines of Madeira were sometimes ripened by plunging them into a trench of fermenting horse dung. The bottles were corked, and thus the wine attained, in a few months, the maturity of a voyage at sea. This, however, may be doubted; because, at sea, not only a particular temperature, but a considerable agitation is kept up. A pipe of Madeira, attached to the beam of a steam-engine, in the warm engine-house, is said to have produced the effect desired. Madeira is, or rather was, in perfection in twenty years. The vine disease has suddenly ruined this far-famed wine, and the unfortunate people of the island that produced it. A very fine sample of this wine the Editor received from Mr J. R. HUTTON of Liverpool—a nutty flavor, and yielded 15·69 per cent. of alcohol.

The wines of Spain are quite distinct from those of Portugal, as well as of France. Many of them are superior of their class, and of the white wines in particular; they constitute the largest quantity of any single foreign wine, red or white, entered in England for home consumption. The wines of Spain, except those of Andalusia, in which much British capital is invested, are carelessly made; but their firmness, just alcohol, resistance to what would ruin very delicate growths in the North, arising from a warm and genial climate, prevent their merits from passing unappreciated. The fine red wine of La Mancha, the Val de Penas, was, until recently, carried about only in pitched skins on the backs of mules. The great exports of wine are from Cadiz and Malaga. The sherry is made near the town of Xeres de la Frontera, nine miles from Port St. Mary's, across the harbor of Cadiz. The grapes are left on the tree until they are shrivelled by the sun's heat, and when plucked remain exposed to it some time before they are pressed. The fermentation is generally left to take care of itself, with all the scum it forms; and yet the wine is so fine that very rarely mischief occurs to it. Racked after the vintage, and constantly under the eyes of the agents or principals of foreign houses, resident on the spot, the management is carefully scrutinized. The grapes here are sprinkled with powdered gypsum, once locally termed *giesso* or *jess.* The must ferments in the cask left entirely to itself. It is racked in March. The casks are left open in all temperatures, and sometimes in the open air without ill effect. A good cellar, so named in France or the North, is not thought of moment here. While fermenting, the bungs are so open as to allow the easy escape of the carbonic gas. Ropiness, dreaded elsewhere under such treatment, is very rarely observed. The natural color of the pure wine is pale; the colored are from a blending with a dark wine called *arropè*, made by boiling down six butts of must to one, keeping the liquid continually stirred and the surface skimmed, avoiding the accident of burning, on which account the process is slowly conducted. When thick enough, the fire is gradually withdrawn, so that the fluid may cool without any injury from chill. It is then mingled in different proportions with the pale wines, thus constituting colored and brown sherry. Nothing foreign is ever mingled with these wines, except a couple of bottles of very good brandy upon their exportation. The sherry, denominated *amontillado*, is a drier wine than the common sherry, and is often the result of accident. To this wine no addition but of its own class can be made without spoiling, not even a glass of brandy. A sample of this pure wine the Editor received from the highly respectable house of Messrs. CHILLINGWORTH and SON of London. It had a superb flavor, *and only contained* 11·50 *per cent. of alcohol*—proving it to be a *pure* wine. Of a hundred butts from the same vineyard, some will be amontillado without it being possible to discover the cause. Thus the constituent parts in amontillado, if supposed exactly balanced, raised the question, Why should this occur in a small portion only of a larger quantity? When it is made, the grapes are plucked a week or two before those for the other wine, but the treatment is just the same. The wines that pass for sherry in England in taverns, are generally made-up wines, or good mingled with inferior or low wines. Another species of wine which may come under the sherry denomination is that called Manzanilla—light, delicate, and straw-colored; it is not always liked at first. It derives its name, some say, from a village near Seville, and as others suppose, from Manzanilla, a small apple. Neither surmise is correct. Manzanilla is the camomile, and there is something of the taste of that plant in its flavor. It is delicate and will admit of no foreign mixture. The dryness shows that the glucose and vegetal extract are well balanced in its fermentation. It is produced from the Rustan grape. The wines of Malaga are of ancient date, and the vines are grown near sugar canes, the only spot in Europe where the latter are found. The bastardo grape makes the sweet wine. The must is conveyed from the press, half fermented, to the merchants' stores in sheepskins, and the wines are sent to all parts of the world unbrandied, except to England. The mountain wine is made in Malaga, and one species is called wine of pears, because that fruit is steeped in it. There is also a cherry wine, called *guindas*, made there. It is much flavored with the cherries. There are many excellent wines in the interior of Spain, but made unpalatable from bad management in the fermentation, exemplifying the Spanish proverb—*To cry wine and sell vinegar.*

The dry wines of Xeres and Malaga, as well as those of Teneriffe, were formerly called *sacks*, and the sweet also. In 1598, in Hakluyt, it is stated by one who resided eight years at Teneriffe, that it produced three kinds of wine—Canary, Malvasia, and Verdona, *which may all go under the denomination of sack.* The wine of different ages is mingled in Andalusia, the newest with old of the purest quality.

The wines of Andalusia are rarely sulphured, from fear of the taste remaining, and on account of English prejudices. Some Englishmen complained of the taste where sulphur had never been used. Here the stalks, and often not even the skins of the grapes, are suffered to ferment in the must. The wines are white, and color is not wanted. In France the stalks are left in the must according to the nature of the season; if fine they remain. In Spain the glucose abounds in the grape; and were it not for the practice of leaving the scum on the wine, and even returning it under the idea of supporting the wine, none would ever become acid. The system of large vats, so friendly to a beneficial fermentation, has not been tried there. Nor is it necessary; for in their present state they enter into the largest consumption in the English market. The better wines of Southern Spain yield nearly a fifth part of alcohol on distillation, and the quality so returned is excellent, and only inferior to the best of France. The tintilla wine of Rota is a red of Andalusia, generally taken as a cordial from its extreme richness. In Alicant a wine is made from the same kind of grape, which holds much tannin, precipitating a species of animal gelatin. It is of an orange-red color, rough, and somewhat bitter. In Catalonia the wines are generally good, and of the red species. Vinaroza and Benicarlo produce good red wines, much of which passes for port in England, either mingled with it or flavored, so as to secure the similitude. This wine is of a wholesome quality. The malmsey of Sitges is white. In Arragon, the wine of Carinena is the best. A muscadine named Fuençaral, is made near Madrid, and a fine dessert wine at Peralta in Navarre.

The wines of Spain have the ascendancy in England, perhaps from their freedom from acidity, owing in part to their treatment in the vat with gypsum, to which must be added their own natural tendency and strength, as seen on their exposure to the atmosphere under circumstances in which the wines of other countries would run rapidly into the acetous state. Wines which contain much of the gluten, are more susceptible of the acetous fermentation than those in which it is more sparingly dispensed; and the latter is the case with the wines of the Xeres district, in which little or none remains after fermentation, without half the trouble in racking and fining which is bestowed on other wines. There can be no doubt, this refers to the white wines of that part of Spain alone when the spirituous fermentation has ceased. The little brandy added, and often none at all, to the best wines of Xeres, as is evidenced in the beautiful sample of Messrs. CHILLINGWORTH above referred to, shows how well their constituent parts are adapted for preservation, compared with some ports and oftentimes their twenty gallons of artificial brandy. It is only to the meagre wines of the country—mingled with a little of the good, and called *low sherries*—that brandy is added, to render the wine more agreeable to the corrupted taste of the English public, which is thus to be satisfied with brandy and wine in a state of mixture, in place of brandy and water. The intemperate use of pure wine when indulged, is never followed by those disorders so common and fatal in the use of the favorite dull fiery wines of the generality of persons in England, particularly in the class called hepatic affections. Brisk, lively, natural wine, is totally distinct in its action on the human frame from that of the brandy wines medicated for a perverted taste. The effect of pure wine in excess is transient; of brandied wine it need not be detailed. The Editor is convinced, from investigations and analyses, that there is no more *necessity* to add brandy to port than sulphuric acid to vinegar. If the liquid be well fermented, sound, and good, any addition is pernicious and wicked.

There is no just ground for believing that brandy will prevent acetous fermentation, although the common notion is that it will do so. It is incredible how far custom goes in effecting error, and preventing its correction, often indeed irremediably. A merchant of good sense desired to have sent him, even if smuggled out of Oporto, half a dozen pipes of port-wine without a drop of brandy. His correspondent would only send him one in reply to the order, being certain *that without brandy it would not keep.* The wine came and remained good in the cellar for years till drank out. The Oporto merchant did not know, that for forty or fifty years after the Northern treaty of 1703, little or no brandy was put into a wine of a very full body, nor that Sir EDWARD BARRY complained in 1773 of these wines becoming too hot. It was not until the end of the last century that they were so fully deluged in artificial spirit—introduced at first under the idea of their preservation, and continued, perhaps increased, by fevered stomachs, which called for deep colored, sweet, and strong; in other words, for more elderberry, sugar, and alcohol.

Brandy in a small quantity will not stop the acetous fermentation in vinegar, for it becomes itself acetified, and makes the vinegar stronger. That one-seventeenth part alcohol should succeed in so doing, as some experimentalists aver, is met by other facts; for acetous fermentation is very easily produced in wine containing an eighth part of alcohol. It is still possible that alcohol added in a sufficient quantity may suspend or retard the fermentation, owing, perhaps, to its not mixing with the natural alcohol of the wine. Chemistry has not yet made this point clear; but it would seem that the general notion of vinous preservation through alcohol, unless in a ruinous quantity, as it is applied in port, sometimes to more than a fifth of its bulk, is very erroneous. The Editor has found port sold in some of the hotels with *thirty-five* per cent. of brandy!

The fact is, that the usage at first, from whatever cause, gave a desire for strong wine in England; and there was the advantage that the growths of bad and good years flung into large vats, and well mingled with brandy, gave a product of that middle-class wine artificially so made, which paid better than a little choice at a high price, and a good deal at a very low figure. It must be observed, too, that in most Northern countries, except France and those yet more to the South, there is a continued craving after alcoholic strength. This has been the case in all ages of the world. The Englishman has his wine medicated until spoiled with brandy; the Persians infuse poppies and similar things for the same end. There is ever a craving for increased stimulants, which, not found in the wine itself, must be added. The Greeks and Romans medicated their wines, or rather perfumed them with various substances. The holy scriptures have left evidence of this, even in the earliest times of the Jews. The alcohol in wine placed there by nature seems to have its parts separated, and to be rendered comparatively innoxious compared to that added unnaturally; and, in the former case, will not readily intoxicate like alcohol mingled with water, milk, and similar liquids. The Jews had no knowledge of alcohol or the still, and endeavored to render their wines more stimulating by their deterioration, as is done at present another way. They had a general term for fermented liquids of all kinds—*shekhar;* but the words, *strong drink* or *mixed wine* are denounced, meaning wine with spices, and stimulating aromatic drugs. *Jahin* or *Yayin*—the *j* is pronounced as *t*—is the term for wine in general; *sobhe* is sometimes used figuratively for the same liquor, and *tirosh* for new wine. But *shekhar* means strong and medicated wine, of which honey was one ingredient, as well as spices and herbs. In the time of AUGUSTUS CÆSAR honey was mingled with his wine, and exposed to the sun, perhaps fermented in it; and as honey contains grape-sugar, it would necessarily strengthen the alcoholic principle, if there remained any gluten, for the emperor could drink no more than a pint of it at a time. Alcohol is formed by nature in every human stomach to a certain extent, according to an eminent chemist, and so far must be congenial to it. The reasonable use of natural wine is often highly advantageous. Discoveries in relation to the combination of alcohol with wine are yet to be made, but it remains certain that it is one of the vinous elementary constituents. Medical men will designate the difference between the effect of wine with its alcohol on the human economy, and the effect of alcohol combined with water. The ebriety produced by champagne in which carbonic gas and alcohol are combined, and that produced by pure claret or chambertin with port and madeira, are obvious to all who move in society where good wines are taken. The effects so lively and airy of the one, with the dull sedative state produced by the last, a blunted quiescent state not easily disturbed, but when disturbed not easily appeasable—indicate different effects from causes, no satisfactory definition of which has yet been obtained.

There has been much dispute regarding the alcoholic strength of wines. There is no reason whatever to dissent from BRANDE's analysis of a considerable variety, made with great care, and there is little difficulty in making the test correctly enough; but the utility is only comparative, because the particular wine to which the test is applied must be taken for itself alone, according to the nature and produce of the grape for the year of the vintage, and not for a succession of years, nor for the same sorts generally; and the like holds good with all the constituent parts, and those slight traces of foreign substances, from differences of soil and plant, and little more, continually perceptible in wines. The same vines for two successive years will not bear fruit so exactly similar, as that some difference shall not be detected in the wine, and in the different proportions of its alcohol. The nature of the season in the same vineyard, and often under similar circumstances, will cause unaccountable changes. A warm year causes the saccharine principle to be abundant, and, yielding more alcohol, gives a stronger wine, as is evidenced upon distillation. Nor is this natural effect more an impediment to classing wines by their alcoholic strength, than that of throwing in brandy, as in Portugal, during fermentation. By the wine being artificially brandied is prevented an accurate knowledge of its alcoholic strength, in the kind most commonly used in the British islands, as no two samples can be expected to show the same result. Thus it arose that the analysis of Dr. **Brande** was wrongfully censured, because it did not appear to be exactly what everybody supposed.

The Editor is of opinion that no port wine contains naturally more than fifteen per cent. of spirit—four or five per cent. are afterwards added to insure the wine keeping for years, in which time the artificial spirit becomes perfectly blended and mellowed in the wine.

The simplest method of ascertaining the amount of alcohol contained in wine is to distil the spirit from the wine, determining its specific gravity and quantity, and compare it with the quantity of wine taken; of course one of the first things to be considered, is how much wine to distil. The Editor takes generally one-third, and determines the alcoholic contents from it. If, for example, in the distillate thirty-three parts out of a hundred are composed of alcohol, the quantity of alcohol in the wine will be 11 per cent. for $\frac{33}{3} = 11$.

In the case of strong wines it is advisable to distil even more than a third, especially if a glass retort and water bath are used. Let the distillation be continued till at least half has passed over. If the density of the distillate is such as to yield twenty-five per cent. of alcohol, then $\frac{25}{2} = 12{\cdot}5$ per cent. of alcohol.

In strong new wines, undecomposed sugar and vegetal extractive matter may cause the evolution of more alcohol during the insensible fermentation. It may be presumed, notwithstanding, that if the quantity of alcohol in any wine exceed twenty per cent. it has been added artificially. All bottled wines, which improve at all, become sweeter, and old wines always appear to have gained in sugar. A very generous wine of the Drôme, in France, will afford a third of its weight in the brandy of commerce; in the department of the Herault there will not be more than a fourth part; in the Côte d'Or about an eighth of what is called prime brandy; in the department of the Charente, a still, charged with two hundred and forty litres of wine, yields from twenty-four to twenty-six of spirit, or about a tenth of the volume of the wine, and a little more in quantity of the second-class spirit; in the department of the Gard, from the same quantity of wine, forty litres of prime spirit, and about the same quantity of the second class. From these products it is easy to approximate to correctness in regard to the amount of spirit in wine, and thus it is seen that one-third spirit is given in first and second brandy of the Gard, while there is often a third distillation, which is not included.

In France it is found necessary to accommodate the Northern palate, by adding ten per cent. to the wines supplied to that part of Europe.

A tale, that **Brande** had only tested adulterated wines palmed off upon him for genuine, was as silly as spiteful. Dr. **Brande** took the wines as he found them in the hands of the merchant, in a state awaiting consumption; and no rival examination showed a greater difference than might be expected to exist on all similar trials. The reader must bear in mind that it is nearly half a century since Professor **Brande** analysed the wines referred to. The Editor has always considered the per centage of alcohol given in genuine port to be too high, and this seems to be corroborated by the fact that samples of port, vintages 1820—1834, *et cetera*, kindly forwarded to him by Messrs. **Chillingworth** for experimental purposes, never gave more than *eighteen per cent. of pure spirit.* The 1820 had a specific gravity of ·9945, and the distillate ·9740 = 18·01 of alcohol; and the 1834 had a density of 1·0163, and the distillate ·9723 = 18·99 of alcohol. Extractive matter in 1820 was 5·140, and in the 1834, 5·976 per cent. There is too frequently a disposition prevalent to cavil at scientific men and their statements because they are novel, or do not chime in with preconceived notions. The nature of the combination of the natural alcohol with wines is not now understood, but its effects just noted are undeniable. This combination cannot be supposed to be any other than one of those secrets, the discovery of which science will one day lay open. Annexed are the results of **Brande**, **Prout**, and others, as to the alcohol contained in the well-known wines in common usage.

PORTUGUESE WINES.	Alcohol in 100 parts.	Specific gravity.	Analyst.
Port,	25·83	—	Brande.
Do.	24·89	—	Do.
Do.	23·71	—	Do.
Do.	23·39	—	Do.
Do.	22·30	—	Do.
Do.	21·40	—	Do.
Do.	19·00	—	Do.
Vinho de Ramo,	15·62	—	Prout.
Do. average,	22·96	—	Brande.
Do. average,	20·64	0·9890	Prout.
Do. weakest,	14·97	—	Christison.
Do. strongest,	17·10	—	Do.
Vinho de Ramo, mean of seven samples,	16·20	—	Do.
White port,	14·97	—	Do.
Colares,	19·75	—	Brande.
Carcavellos,	19·20	—	Do.
Do.	18·10	—	Do.
Do. average,	18.65	—	Do.
Lisbon,	18·94	—	Do.
Do. dry,	16·14	—	Christison.
Bucellas,	18·49	—	Brande.
Vidonia,	19·25	—	Do.
SPANISH.			
Sherry,	16·81	—	Brande.
Do.	19·83	—	Do.
Do.	18·79	—	Do.
Do.	18·25	—	Do.
Do.	21·34	0·9752	Do.
Do. average,	17·17	—	Do.
Sherry, very old,	23·86	—	Prout.
Do. weakest,	13·98	—	Christison.
Do. strongest,	16·17	—	Do.
Mean of thirteen kinds,	15·37	—	Do.
Do. long kept and East Indian,	14·72	—	Do.
Mean of Madre de Xeres,	16·90	—	Do.
Amontillado,	12·63	—	Do.
Tint,	13·30	—	Brande.
Alba Flora,	17·26	—	Do.
Malaga, 166[illegible],	18·94	—	Do.
Do.	17·26	—	Do.

MADEIRA ISLANDS, ET CETERA.	Alcohol in 100 parts.	Specific gravity.	Analyst.
Madeira,	24·42	—	Brande.
Do.	23·93	—	Do.
Do.	19·24	—	Do.
Do. average,	22·27	—	Do.
Do. Sercial,	27·40	—	Do.
Do. do.	15·45	—	Christison.
East India, in cask,	16·90	—	Do.
Do. weakest,	14·09	—	Do.
West India, do.,	21·20	0·9908	Prout.
Red Madeira,	22·30	—	Brande.
Do.	18·40	—	Do.
Do. average,	20·51	—	Do.
Malmsey,	16·40	—	Do.
Do.	12·86	—	Christison.
Teneriffe,	19·79	—	Brande.

The analyses of BRANDE are calculated upon eighty-nine per cent. of alcohol and eleven of water; of CHRISTISON and ZIZ upon absolute alcohol.

FRENCH.	Alcohol in 100 parts.	Specific gravity.	Analyst.
Claret,	17·11	—	Brande.
Do.	16·32	—	Do.
Do.	14·08	—	Do.
Do.	12·90	—	Do.
Do. average,	15·10	—	Do.
Do. first growth, 1811,	7·72	—	Christison.
Do. Latour, 1825,	7·78	—	Do.
Do. Rose,	7·61	—	Do.
Do. ordinaire,	8·99	—	Do.
Champagne, still,	13·80	—	Brande.
Do. Mousseaux,	12·80	—	Do.
Do. red,	12·56	—	Do.
Do. pink,	11·30	—	Do.
Do. average,	12·61	—	Do.
Do.	12·10	—	J. Fontenelle.
Do. Burgundy,	16·60	—	Brande
Do.	15·22	—	Do.
Do.	14·53	—	Do.
Do.	11·95	—	Do.
Do. average,	14·57	—	Do.
Do. 20 years in bottle.	12·16	—	Prout.
Hermitage, white,	17·43	—	Brande.
Do. red,	12·32	—	Do.
Côte Roti,	12·32	—	Do.
Roussillon,	19·06	—	Do.
Do.	17·26	—	Do.
Do. average,	18·13	—	Do.
Sauterne,	14·22	—	Do.
Nice,	14·63	—	Do.
Barsac,	13·86	—	Do.
Vin de Grâves,	13·94	—	Brande.
Do.	12·50	—	Do.
Do. average,	12.08	—	Do.
Grenache,	21·24	1·053	Prout.
Frontignan,	12.79	—	Brande.
Rivesaltes,	9·31	—	Christison.
Lunel,	15·52	—	Brande.
Do.	18·01	—	Fontenelle.

SICILIAN AND ITALIAN.			
Marsala,	26·03	—	Brande.
Do.	25·05	—	Do.
Do. average,	25-09	—	Do.
Do. 21 years old,	18·20	—	Prout.
Lissa,	26·47	—	Brande.
Do.	26·35	—	Do.
Do. average,	25·41	—	Do.
Do.	15·90	0·9913	Prout.
Lacryma,	19·70	—	Brande.
Syracuse,	15·28	—	Do.
Do.	30·00	0·9911	Prout.
Etna, red,	18·90	—	Faraday.
Do. white,	18·16	—	Do.
Do. Sinical,	19·00	—	Do.
Do. white Falernian,	18·19	—	Do.
Do. red,	20·00	—	Do.
Aleatico,	16·20	1.020	Prout.

GERMAN.	Alcohol in 100 parts.	Specific gravity.	Analyst.
Hocheimer,	14·37	—	Brande.
Do.	13·0	—	Do.
Do. old in cask,	8·88	—	Do.
Do. average,	12·03	—	Do.
Joannisberger, 1788, 9·38 parts acid in 100 by weight,	8·71	0·9978	Prout.
Rüdesheimer, 1811, 6·22 parts acid in 100 by weight,	10·72	—	Do.
Do. 1800,	12·22	0·9960	Ziz.
Do. superior,	8·40	—	Christison.
Do. inferior,	6·90	—	Do.
Hambacher,	7·35	—	Do.
Oestricher, 1801,	8·46	0·9960	Ziz.
Do. 1802,	10·50	0·9890	Do.
Do. 1804,	10·66	0·9920	Do.
Zornheimer, 1802,	10.11	0·9790	Do.
Do. 1803,	9·00	0·9960	Do.
Do. 1804,	8·75	1·0310	Do.
Bodenheimer, 1802,	13·96	0·9890	Do.
Rhenish, four years, under Soemmering's process, 10·58 parts acid by weight,	7·58	0·9997	Prout.
Do. natural state, 10·58 parts acid in 100,	7·36	0 9992	Do.
Do. three years under Soemmering's process, 8·4 parts acid in 100 by weight,	7·00	0·9968	Do.
Steinberger,	10·90	1·0025	Geiger.
Marcobrunner,	11·60	0·9985	Do.
Leibfrauenmilch,	10·60	0·9939	Do.
Geisenheimer,	12·60	0·9945	Do.

HUNGARIAN.			
Tokay,	9·33	1·054	Brande.

PERSIAN.			
Shiraz,	15·52	—	Do.
Do.	12·95	—	Christison.
Do.	19·80	0.9944	Prout.

CAPE OF GOOD HOPE.			
Cape Madeira,	22·94	—	Brande.
Do.	20·50	—	Do.
Do.	18·11	—	Do.
Do. average,	29·51	—	Do.
Cape Muscat,	18·25	—	Do.
Constantia, white,	19·75	—	Do.
Do. red,	18·92	—	Do.
Do. do.	14·50	1·081	Prout.

REDDING has given an analysis in another form, as follows; but has not stated his authority:—

	Absolute Alcohol.	
	Ounces.	Drachms.
Port, in bottle of 26 oz., seven years in glass,	2	7
Do. 25½ oz. one year in bottle, two in wood,	2	6
Pale sherry, 25 oz., three years old,	2	4
Another specimen,	2	7
Madeira, 25½ oz., two years old,	2	5
Cape, 25 oz., one year old,	2	8
Old hock, 21 oz.,	1	0
Brandy, 24 oz.,	10	0
Rum, 24½ oz.,	9	8

MULDER, who has had great experience in the analyses of wines and spirits, states that alcohol varied as follows:—

	Per cent.		Per cent. by measure.
Port	20·70	to	23·20
Sherry	15·40	……	24·70
Madeira	19·00	……	19·70
Marsala	19·90	……	21·10
Claret	9·10	……	11·10
Burgundy	10·10	……	13·20
Rhine wine	9·50	……	13·00
Moselle	8·70	……	9·40
Champagne	14·10	……	14·80
Brandy	52·40	……	53·80

Eighteen per cent. alcohol by weight are equal to about twenty per cent. by volume.

The wines of Palestine, Syria, and Asia Minor vary much in alcoholic strength. Those analyzed by Professor HITCHCOCK of Amherst College, United States of America, contained from ten to eighteen per cent. of alcohol, or nearly as much as the European wines, except those of Oporto, Madeira, and Sicily, or the low wines of Spain that are brandied.

Of late years Australia has become rather prominent as a wine-producing country. The Editor's brother, Mr. FREDERIC MUSPRATT, who has resided there for some years, writes as follows :—

Wine has been made in Australia during the last thirty years, but has not been known in the towns till within the last ten years, owing to the great demand for it in the country. The vine flourishes more or less in all these latitudes, but the climate of New South Wales must be admitted to be the best adapted for wine-growing, and vineyards are established on the banks of the Hawkesbury, the Nepean, the Hunter, the Williams, and the Paterson, which are capable of being greatly augmented, to meet any demand there may be made for wine; and a rapidly increasing population will doubtless hasten their extension. The quantity of wine produced in 1857 was about three hundred thousand gallons.

The wines best known in Sydney and Melbourne are Irrawang, Tomago, Caewarra, Camden Park, Kinross, Kaludah, Porphyry, Tanilba, Wivenhoe, *et cetera*, and the *crû*—characteristic flavor—of the different varieties is as marked as is that of *Chateau Lafitte*, *Margaux*, or other European wines.

A Burgundy wine is best at Irrawang; a champagne at Kaludah and Caewarra; a medoc at Tomago, Kinross, and Tanilba; a hermitage at Porphyry; a muscat at Camden Park; and a Grâves at Tanilba.

The vineyards are principally worked by Germans, and the cellar-masters have learned their craft at Frankfort-on-the-Maine in Europe; so the local prejudice against colonial wine, manufactured formerly under the superintendence of squatters, who never had any experience in wine-making, is rapidly disappearing, the grape being richer in sugar than that grown on the Rhine-board. *The ordinary wine* of the country is considered generally to be superior to that of Germany. There has not been time to test, on a large scale, the capability of producing extremely fine wines, but, judging from the fact, that wine thirty years old is as rich in flavor and bouquet as wine the same age in Europe, there can be but little question as to the quality. At the Paris Exhibition of 1855, the jury, upon tasting a red wine, two years old, called it a *joli vin, beaucoup d'avenir*, and awarded it one of its highest numbers. All present expressed their surprise at the result of the examination, and highly approved of the wines. The foreman said they were perfectly astonished at the quality of the Australian wines, and were unanimous in giving them a place, for strength and flavor, between the wines of Madeira and those of the *Côte du Rhone.*

A Sydney trade-circular, in describing the wines at present in the market, says :—The wines of this colony are essentially Australian in general character. They assimilate to the French and German wines. Some are considered by connoisseurs to resemble hock, Sauterne, claret, Burgundy, and the like, but no attempt is made to imitate these or any other wines. Of course, the vines are in great variety, but, from whatever description of grapes they are made, each vineyard has a peculiar local character, distinguishable by vinists. The Camden wines will first be noticed. These are of three sorts, namely—white, which resembles the Rhenish wine; red, which approaches Burgundy in taste; and muscat, rather like the Frontignac of the Cape, malmsey, or Madeira. Now for the Irrawang wines. The white is considered like hock or Sauterne; of the red there is at present no stock; and the sparkling Muratta is a very fair champagne. Next, the Wivenhoe wines will be referred to. These are—the white Muscat, resembling hock; red, corresponding in flavor with Rhenish wines; Madeira, which is of a Frontignac description; and Reissling. There are some wines grown at Oatlands, near Paramatta—the red resembles a claret, and the white corresponds with a light French wine. Under the head of Notes and Queries in the *Spectator*, is the following :—The samples of Australian wine at the Paris Exhibition have earned special commendation. When the horticulturists of that colony shall have succeeded in extending the cultivation of the vine over the land of the dreary Encalyptus, one may imagine that it is destined to the nurture of a British BACCHUS, and may look forward to the importation of Australian wines; and upon its arid soil, even upon the chasm of pools that its rivers present in the summer, would be exhibited the same miracle which is to be seen in the South of Europe, the juicy grape growing upon a parched soil, and for a season would be clothed with the loveliest foliage under the sun. Fancy the change of character that must come over the British stock habitually living in such scenes, under such a sun, with such a diet. It will be an experiment somewhat such as the world might have witnessed had the Saxon been planted in Italy. These queries are curious, as indicating the notions of the untravelled; but parties are daily getting more accurate knowledge as to the actual capabilities of the British Colonies.

The vineyards in the neighborhood of Adelaide, South Australia, are rapidly extending, and on the banks of the Murray and Murrumbidgee; the wines that are grown there will bear comparison with those of other lands. The only drawback to a rapid increase in the wines made in Australia lies in the dearness of labor; but as all the farmers along the thousands of miles of river banks are all planting their small vineyards—which may be tended by their wives and children—and as merchants, who will buy the juice and await its ripening, are establishing themselves at convenient places, there is every prospect of the trade becoming greatly enlarged.

In the ripening of wines Australia possesses an advantage over Europe. As there is no winter there, so is there no check to the fermentation after the juice has been removed from the vats to the casks. This check to the fermentation in Europe is the cause of much wine *fouling*, and is the mother of many of the so called *sicknesses in wines.* This is a source of great anxiety to many of the large European *vignerons.* On account of the hot winds in Australia, the vines are pruned low; and as this method, combined with a hot sun, causes more *must* to be in the grape than is usual in Europe, it is found that the fermenting juice will, as a rule, bear a large quantity of *stalk;* the consequence is, that the elements of bouquet are much more prominent than with wines of the same strength in Europe.

The foregoing remarks are well worthy of attention. Good and sound wines doubtless have been made in Australia; but the Editor is not so certain whether the English will ever admit any wine produced in the colonies to be equal in that beautiful aroma—which science has not yet been able positively to assert what it is—and flavor belonging to the first-class wines of Europe—Johannisberg, Sauterne, Rudesheimer, Liebfraumilch, *et cetera.*

In 1852, specimens furnished to Baron LIEBIG will explain the result of an attempt at wine-making in that colony. This wine, principally from the grape called the pineau noir and gris, carried a specific gravity of 0·992, and gave 16·20 per cent. of alcohol; 0·505 of free acid; 3·265 of dry residue; and 0·498 of incombustible ashy constituents. Another species of white wine grown at Irrawang had a specific gravity of 0·94; gave out thirteen per cent. of alcohol; 0·66 of free acid; 3·313 of dry residue, chiefly saccharine; and 0·563 per cent. of ashy constituents—proportions met with in some of the European wines, particularly the German. LIEBIG also analyzed other wines of Australia, and among them one obtained from the white muscat grape, which gave 19·53 per cent. of alcohol and 0·64 of free acid.

The wines of South America have not been analyzed. They are scarcely known in Europe. There is, however, a red wine made at Chili which is much liked by Frenchmen, and is considered a very fine *vin ordinaire;* instances being known of French men-of-war putting in to Chili and stocking their vessels with hogsheads of it.

The difference in the intoxicating effect of wine, and brandy and water, it has been asserted does not exist. Professor BECK, taking brandy at 53·39 of alcohol, calculated strong Madeira at 48·26; weaker Madeira, 36·14; port, average, 42·33; Bucellas, 35·21; sherry, 33·75; Sauterne, 24·34; claret, 21·38. He is of opinion that the difference between wine and brandy and water is more fanciful than real. New wine is more intoxicating than old, although the latter is more spirituous; and, according to SOEMMERING, loses of its aqueous parts by age. BRANDE, with good reason, supposes that when brandy and water are allowed a sufficient time for combination, the intoxicating power may not be more than that of wine containing an equivalent of brandy. Thus the effect of brandy and water arises from their imperfect union. On the other hand, it is certain, that the evil effects of the two, when taken in excess, upon the animal system are very different. Fine pale cognac—HENNESSY or RENAULT'S—with water, is often prescribed for invalids, and with great success. The Editor is of opinion that such a beverage taken constantly is less injurious than heavy, and especially drugged wines.

In some places in the North of Europe wine has been exposed to severe frost, under the idea of imparting strength to it, by drawing off the unfrozen portion. In the Augustan age, when the Euxine sea used to be frozen over, the wine in the casks, it is said, was cut with hatchets. Mr. PARKES experimented on wine exposed to 22° below the freezing point. He could discover no difference in taste between the fluid frozen and unfrozen, and thought the unfrozen the more vapid of the two. Of five hundred and sixty grains of port wine, five hundred and forty remained liquid; and of sherry two hundred and eighty-five grains were frozen, and one thousand and fifty-six remained in a fluid state—a result not in accordance with the experience of the colder wine countries of Europe.

The various matters discoverable in wine are not all found in the same growths. Less or more in some, and none at all in other kinds, with ever varying quantities, render analysis only good in relation to single specimens, and of no service in laying down a general rule for all. Thus water, sugar, alcohol, gum, extractive and nitrogenous matter, or albumen; the bitartrate of potassa, sulphate of potassa, chlorides of potassium and sodium, and in red wine coloring matter, and tannin from the stalks; carbonic acid in sparkling wine, and a perfume or bouquet, a species of ether—enanthic, acetic, *et cetera*—found in the fermentation, and citric acid—a mere trace of the latter—have been found in wine. Malic and gallic acid were thought at one time, with tartar and sugar, adding the gluten, to be almost the entire of the principles discoverable, and that all wines were the same in this respect; but science has undeceived the world upon this point. The amount of sugar in some sweet wines is full thirty per cent. according to PROUST. White wines are more perfect than red, and will endure longer; perhaps arising from the absence of the acid taken up by gypsum in the making, which cannot be used in red wines. The color of the red wines sometimes approaches to black from intensity. Indeed, a powerful wine in France carries the name of the Black wine of Cahors, generally used for strengthening weak-bodied or light-colored wines. Port wine of the vintage 1812, and that of 1820—CHILLINGWORTH—are nearly black, although upwards of forty years old. From pink to black in red exist, and from water to a deep golden hue in white wines, and even a green color in the wines of Cotnar. Amber and brown in different shades are to be met with, but no merit in regard to the quality of the wine attaches to the hue, however agreeable one more than another may be to the vision. Perhaps the clarets—so named from the French *clairet,* which, however, attaches to a different species—hold the middle place in regard to color, between the light red and black. The coloring matter in red wines may be obtained by an exposure of the bottle to the sun's rays, when it will fall in flakes; the taste of the wine remains unaltered. Before adding lime water the coloring matter is precipitated with the insoluble salt formed by the wine and acid of the wine in union. The finer wines are generally those in which the color is most attended to by the maker, and the rivalry in this respect is considerable. It is a matter in which prejudice operates. Many people cannot be persuaded that a pure red wine, of a light color, may be far superior as a wine in every good quality to one deeply colored, even when perhaps, as in port wine, it is aided by the elderberry.

When red wines lose color on the Continent they are said to be *rancio*, rusty; in England tawny. The coloring matter deepens on the deposit of tartar, and the tawny hue arises from age. Heat, too, will injure the color, which is thus not necessary to the flavor of the wine, being no way dependent upon it. Carbonate of potassa, sometimes formed in wine, injures both the color and flavor. It arises from the decomposition of the tartar, and in France is called the *tornure*. A little tartaric acid being added, the potassa forms cream of tartar, depositing crystals.

Wines grow darker as they ameliorate up to a certain point, but this is not uniformly the case. The alcohol in the wine, diminishing by evaporation, has no relation to this change; indeed, it is probable, that the aqueous portion evaporates rather than the spirituous. The specific gravity of wine increases under those circumstances. Many affirm that the alcohol in bottled wine increases by age; MULDER asserts that such a statement is thoroughly false, the formation of alcohol in the bottles being impossible. SOEMMERING discovered, that there were substances which permitted the aqueous portion of wine to escape more freely than the alcoholic. Equal parts of alcohol and water were placed in a glass vessel, and the mouth closed with a piece of bladder.—See ALCOHOL. It was observed, that under the circumstances more water was lost than alcohol, but when the temperature was raised to 62° it passed through the bladder unchanged. From this, and other experiments, SOEMMERING took the idea of ameliorating wine by exposing it to a similar process. He, in consequence, covered a glass vessel full of wine with a bladder, and suffered it to remain eighty-one days aside in a warm dry room. During that time one-half had evaporated, and the residue had acquired a more spirituous, mellow, and agreeable flavor. The color was deepened, a film had formed over the wine, and a deposit of crystals had taken place at the bottom of the glass. The proportion of alcohol had doubled from 4·0 to 8·0. A repetition of the experiment gave the same result, and thus a more rapid mode of ameliorating wine was discovered, than keeping it in wood, to effect the disengagement of the alcohol and water by time. Hence the transportation of wines to a tropical climate and home again, exposing the wine to aqueous evaporation, easily accounted for the beneficial effect, and the same with heat artificially applied. Wines thus exposed, too, deposit rapidly. Thus it is a common trick with port wine-mixers to place the bottles in water, carry it to the boiling point, and then, taking them out and placing them in the cellar, *the crust so admired by the ignorant in port wine is immediately formed.* It has been advanced, in consequence of the foregoing discovery, that the amelioration of wines in the wood is effected mainly by the disengagement of some of their water—the alcohol being retained, or a smaller proportion of alcohol than water being evaporated, the rest of the wine becomes more concentrated—and that for this purpose vessels are most desirable which will retain the alcoholic and permit the aqueous particles to escape. Wine is observed to evaporate more rapidly in chestnut casks than in those of oak or similar close-grained timber. To such an extent is this evaporation carried in chestnut casks, that the French have prohibited the exportation of brandy in any but what are made of oak. Hence it may be conjectured, that the larger the surface of the liquor exposed the more rapid will be the evaporation; and that as the fermentation is quickened by the larger bulk in action, so it is with vinous amelioration. There is probably a limit here, which it would be very desirable to ascertain, but to which discovery no approximation has yet taken place. The Germans of late years, as they have discovered that, beyond the point of maturity in wine, the long keeping once thought of so much importance is not really of any great moment, seem also to have discovered that tuns of a moderate capacity are fully as advantageous as the gigantic vessels, by their fathers deemed of so much moment, for mellowing their Rhine wines.

Wine is continually sophisticated and adulterated, especially such as is of a coarse nature, having no obvious standard of taste. Of such wines port is, from the common usage, and the different flavors imparted to the wines of that name, the most abused. It is clear that a wine of any given species, if pure, will differ very little more in flavor in any season than the strength or weakness of the must will occasion. The main characteristics of the wine will be present. In a first-class Burgundy wine, for example, it will always be possible to distinguish that the wine is the growth of the country assigned, and no other wines will be drank in its place that are not of the same order. This would be the case with all sound good growths, and with the wines of Oporto as well, had they not been continually deprived of their natural character by mingling, coloring, and brandy adulteration. A house—IRELAND and Company of Bristol—was renowned for its excellent Bristol port wine, and a handsome fortune realized. All at once, on the breaking out of the French revolutionary war, Bristol ports were no longer to be had, and IRELAND and Company wound up their affairs, because they could no more obtain the wines of the South of France, for which they were celebrated as port-wine merchants, not a cask of their wines having ever been in Portugal. Now, such a deception could not be practised with Burgundy, champagne, or the finer wines of France.

The Editor has repeatedly had *English-made port* sent to him, but the imitation in no instance deceived him. The *taste* was sufficient to detect the imposition.

The mingling of inferior wines with superior, or with brandy, is not the sophistication for which the chemical professor is so much required to confer a boon upon the public, as in detecting extraneous substances of no vinous character at all. To brandy intermixed with wine, and which never blends with it as the natural alcohol of the wine does, are owing, in many cases, the liver complaints of the wine drinkers in England—a disease rare in wine countries.

The alcohol in wine may be ascertained by adding one part of a concentrated solution of subacetate of lead to eight of wine by measurement. A precipitate is thus formed: agitate the mixture for a few minutes; pour the whole upon a filter; and then collect the fluid. This fluid consists of the spirit and water, with a portion of the lead. Now add by little and little *pure*, warm, dry subcarbonate of potassa—not the salt of tartar, and subcarbonate of potassa of commerce—which has been freed by heat from water. This must be done until the last portion remains undissolved. The spirit in the fluid being thus separated by the potassa abstracting all the water, the former will be found a stratum upon the salt. The experiment should be made in a glass tube, from half an inch to two inches in diameter, graduated into a hundred parts; and thus the quantity of spirit may be read off at sight.

To detect elderberry coloring in port and other red wines, acetate of lead is the simplest test. With pure red wine it throws down a greenish-grey precipitate. A deep blue precipitate is the result of elderberries, logwood, and bilberries. Brazil wood and red sanders are thrown down red. Lime water destroys the color imparted by beet.

Watson in his chemical essays, as to his assertion that lead has been used in wine, is contradicted by the best French chemists, who have never been able to find a trace of its usage, and assert that it cannot be of any service. In England, among the fabricators and amenders of base wines, sugar of lead and litharge have been ignorantly applied for cleansing white wines rapidly, according to their own statements. Ignorance and vice generally travel abreast. Thus to keep wines from turning, some one of the vulgar receipts has proved a very harmless one—Put in fair water a pound of lead which has been melted; then into the cask, pretty warm, and stop it close! Oyster-shell lime has been used for the same purpose, an ounce to two gallons of the wine. Cochineal, to the extent of half an ounce dissolved in wine or brandy, is one means used to improve color; and for port wine the compound called *geropiga* made in Portugal, and imported into England openly, as a *liqueur* solely for sophisticating port wine. Port and claret are rendered rough by baking two quarts of sloes in a gentle oven, or over a slow fire, until their moisture is given out. The fruit is squeezed, and a pint of the liquid is applied to thirty or forty gallons of the wine.

Substances native, such as genuine must, wine, alcohol, or sirup—that is, boiled wine—can alone be tolerated in mixing. All besides is more or less a fraud. The object of mixing litharge, potassa, and tartrate of potassa, is to arrest bad flavor and temper sharpness in new wine. Some substances for color, sugar and honey to sweeten, spices to improve the flavor, and perry and water to increase the volume, are complained of in France. There is a commission there of able chemists, who examine samples of wine with great care. First, as to litharge—a poison—no one instance of its use has ever been detected. In 1824 a petition was presented to the French chamber of deputies, making such a charge against the wine merchants generally, that the public were alarmed, and an inquiry was instituted. The result was, that no single instance of the employment of litharge could be substantiated —that, chemically speaking, litharge was a substance which, from experiment, contributed more to the deterioration than the preservation of the wine, and the merchants had no interest in its use. The petition was rejected as without foundation. In analyses of the wine for fifty-five years, the French council of health never met with the traces of such a substance in wine. They only stated that they had to complain, that too much water and often perry had been mingled to increase the volume of the wine. Sirup of dried raisins had been used with colored water, and fermented and sold to imitate the wines consumed in cabarets, but never any deleterious substances, under countless analyses. M. Jullien experimented upon this substance in 1824. In a litre of musk in a state of acetous fermentation, one gramme and a half of powdered litharge was mingled and agitated several times for twenty-four hours, and then suffered to rest. The wine was tasted two days afterwards, and found as acid as at first, and unchanged in color. It was then filtered, and sulphuric acid being added, the white precipitate of the sulphate of lead was scarcely perceptible; but the sulphide of potassium, in another part of the liquid, caused a precipitate of the color of the lees of the wine. The result of four analyses was, that litharge did not deprive wine of its acidity, and contributed more to its decomposition than preservation; that in any considerable quantity it destroyed it, and that in a small quantity it remained in the wine in a state to be recognized with facility. If used in domestic wines, the same effect would follow. It was probable that the tartar of the wine had been mistaken for it. After all the scientific researches of foreigners into the nature of wine, they have not succeeded in detecting the quantity of perry, water, and not insalubrious ingredients, added by the dishonest dealer.

Frauds in blending wine, often too common, are not managed with substances foreign to the grape. The rinsings of brandy and rum casks, Cape wines, cider, coloring matter, and tartar, or anything which will form a basis with Benecarlos, Figueras, red Cape, mountain, tartar, gum-dragon, cider, for port; and for coloring it red sanders infused for fourteen days in spirit of wine. Port is also made with that wine, twelve gallons; spirit of wine, six; brandy, three; rough fine cider, forty-two. A strong decoction of Brazil wood and alum imitate the favorite crust. Sherry is imitated, but the low-priced wine mingled with Cape answers the end. The notion that lead helps bad wine is current in England. But little faith is to be placed in such reports, since it has not the effect ascribed to it. Sulphide of hydrogen gas will detect lead in wine, turning it deep brown or black. Alum, sometimes used for astringency, or for the purpose of brightening the color, or of clarifying newly made wine, may be detected by first decoloring the wine—if red—by means of animal charcoal, previously washed with hydrochloric acid, filtering, and evaporating the liquid to about one-third of its volume in a porcelain or platinum capsule, and refiltering. If a precipitate has been formed while concentrating; if potassa, soda, or chloride of ammonium produces when poured into the filtrate, a white precipitate soluble with the aid of heat in excess of alkali; if carbonate of potassa or soda produces a white deposit; if nitrate of baryta or or chloride of barium produces also a white precipitate insoluble in acid, *alum is present;* or as NORMANDY further adds, a given portion of the wine may be evaporated to dryness and ignited, the residue treated with a little hydrochloric acid, evaporated to dryness and re-treated with dilute hydrochloric acid. If now the addition of caustic potassa produces a white gelatinous precipitate soluble in excess of alkali, but which is reprecipitated by chloride of ammonium, then alum is present.

Not to follow these deceptions further—the field it may be inferred is a wide one for the investigation of science, by researches into the defects of wine itself, and pointing out proper remedies—the inequality in must of the product of the grape, from so many causes, requires to be obviated; but no rule can yet be laid down by which existing evils can be certainly avoided. Among the curious facts in relation to pure wines are the character of their deposits, so varied in form and density, according to the growth of the vine and temperature of the year when the vintage occurred. Some are oily, others muddy, adhering to the side of the bottle; and some are very light, so that on the least movement they mingle with the wine. Oftentimes the same wines will make a deposit in two different forms in the same bottle, one adhering to the sides or uniting in a mass at the bottom of the wine, the other suspended in the liquor. One species of deposit resembles litharge, and no doubt caused the report of its usage. In champagne wine the deposit is called *depot-pierre*, a precipitate in the form of very fine sand, or little scaly crystals, which are the tartar naturally deposited. All wine residuums contain more or less of this substance, but it is often so enveloped in the oily or muddy parts of the precipitate that it is not apparent. It is heavier than other deposits, and when mingled with the wine does not communicate any bad taste, alters its clearness very little, and when shaking the liquor ceases it falls to the bottom. This deposit is found in the better wines, and those having it preserve their excellence a long time, and are less subject to disarrangements than the wines the residue of which floats in the liquid. In order to investigate the nature of this substance, it is dried and placed upon burning charcoal. In consuming it emits an odor of burnt tartar, and on keeping up the fire, leaves a white residue which is found to be potassa.

The choicest wines keep the longest in bottle, and deposit there so much that, in order to have the wine perfectly limpid, it is necessary to decant them with great care. It is useless to place them in different bottles for no other reason but to secure transparency, as they will soon begin to deposit anew. Unless they are to be removed to a distance, or there is a fear of their acquiring a bad taste, they should remain untouched. This operation, when necessary, is to be performed with great care. Small glass or tinned siphons have been tried for delicate French wines, but not with the desired success. Crape or gauze has its inconveniences. An instrument called a *cannelle-aérifère*, invented by M. JULLIEN, is used for the purpose in France, as well as for chemical transfusions. For champagne more particularly it is well adapted. Wine is sometimes placed in demijohns, which hold from thirty to sixty bottles each, by which means it is well preserved; but the inconvenience of stirring up the deposit is in no way lessened on attempting to transfer their contents.

The disproportionate allowance of brandy thrown into wine is after all the great evil encountered in the wines destined for British consumption, and this is always to be detected by science. All wines of the highest class are deemed too weak and thin. The merchant imagines that it prevents acetous fermentation, and he knows that it blends all qualities into that which is most plentiful. Dr. M'CULLOCH denied that it suspends acetification; Mr. CADET says, that if administered to the one-seventieth of the entire value it will do so. Alcohol is not separated by the action of heat, since it has been effected at 56°; but, however, this may be, wine to which brandy has been artificially added, affects the nervous system to a degree far greater than wine in the natural state, and chemistry has not yet been successful in discovering any theory which will account for it. The following tables show the importations of wine and the amount for home consumption for the years mentioned in the respective columns:—

TABLE OF WINE IMPORTATIONS.

Years.	Tuns. French.	Tuns. Portuguese.
1675	7.495	20
1676	9,645	83
1677	6,789	176
1678	7,212	199

French war—wine prohibited.

Years	Tuns.	Tuns.
1679	3	1,013
1680	1	1,003
1681	..	1,718
1682	..	13,860
1683	..	16,772
1684	..	11,611
1685	..	12,885

French again admitted.

Years.	Tuns.	Tuns.
1686	12,760	286
1687	15,518	327
1688	14,218	448
1689	11,109	579

Here the French imports again interrupted. From 1697 inclusive, the returns were more exact and given in gallons, *videlicet*, together, French, Spanish, Portuguese, and Rhenish.

Years.	Tuns.	Hhds.	Galls.	Years.	Tuns.	Hhds	Galls.
1697	13,086	3	43	1707	12,962	0	16
1698	12,974	2	15	1708	14,380	0	50
1699	21,553	3	25	1709	13,338	1	48
1700	23,502	0	10	1710	15,869	0	56
1701	21,443	2	23	1711	15,481	2	14
1702	15,725	1	62	1712	12,677	1	27
1703	11,092	2	42	1713	15,937	1	8
1704	13,811	1	57	1714	18,747	1	57
1705	12,070	1	17	1715	21,751	0	9
1706	10,973	2	31	1716	18,834	3	7

Years.	Tuns.	Hhds.	Galls.
1717	22,260	3	58
1718	23,875	1	48
1719	20,510	2	13
1720	19,141	0	44
1721	25,263	0	45
1722	25,470	0	42
1723	22,415	1	1
1724	23,075	3	8
1725	24,722	3	35
1726	19,334	0	24
1727	21,064	3	61
1728	30,045	2	32
1729	25,672	3	50
1730	19,823	3	31
1731	24,239	1	58
1732	21,384	0	11
1733	21,420	1	57
1734	21,264	1	47
1735	24,416	1	28
1736	20,763	0	10
1737	26,605	1	38
1738	22,171	2	1
1739	18,594	3	28
1740	15,198	3	60
1741	17,178	1	3
1742	16,715	3	58
1743	17,655	0	34
1744	10,276	2	60
1745	16,034	1	34
1746	12,205	1	11
1747	14,560	2	32
1748	15,135	1	16
1749	21,555	0	35
1750	15,456	2	11
1751	14,788	0	2
1752	13,708	2	52
1753	18,857	0	20
1754	14,982	3	50
1755	16,544	2	22
1756	12,264	2	18
1757	14,050	2	30
1758	15,896	1	54
1759	15,405	2	19
1760	15,427	3	47
1761	14,602	3	46
1762	16,097	0	1
1763	17,082	3	21
1764	17,390	1	42
1765	18,132	1	4
1766	18,472	0	14
1767	17,087	3	5
1768	18,580	0	58
1769	18,371	2	30
1770	16,724	0	40
1771	16,874	2	12
1772	15,597	2	42
1773	16,431	3	20
1774	17,992	1	20
1775	17,736	0	13
1776	16,734	0	36
1777	18,217	2	60
1778	16,343	0	51
1779	12,760	2	10
1780	20.514	2	39
1781	13,311	3	20
1782	9,791	0	39
1783	13,624	1	51
1784	14,499	0	56
1785	16,287	0	$58\frac{1}{2}$
1786	16,242	3	53
1787	23,324	3	33
1788	25,560	3	52
1789	26,299	2	60
1790	29,144	3	13
1791	33,155	1	33
1792	35,525	3	51
1793	22,788	3	40
1794	30,259	2	2
1795	35.608	3	54
1796	23,693	1	37
1797	15,904	2	30
1798	23,287	3	49
1799	33,419	3	7
1800	32,332	1	26
1801	38,893	1	21
1802	30,407	0	53
1803	37,913	1	62
1804	19,419	3	2
1805	33,463	0	55
1806	35,910	0	55
1807	39,789	3	29
1808	47,143	3	49
1809	49,762	3	17
1810	47,058	3	25
1811	20.787	1	4
1812	35,082	1	$17\frac{1}{2}$
1813	..	..	..
1814	31,465	2	36
1815	30,874	0	$20\frac{3}{4}$
1816	18,218	0	$57\frac{1}{5}$
1817	27,073	0	$1\frac{2}{5}$
1818	35,763	2	$9\frac{2}{5}$
1819	23,407	0	$33\frac{7}{10}$
1820	22,781	1	$55\frac{7}{20}$
1821	24,125	0	$2\frac{2}{20}$
1822	27,454	2	25

The Methuen treaty to favor Portugal at the expense of France was signed in 1703—the duty on French wine to be one-third more than on that of Portugal. A tun of wine is two pipes, four hogsheads, or two hundred and fifty gallons old measure, or two hundred and thirty-one cubic inches. From the year 1785 the returns include all sorts and quantities of wine, however small. In 1813 the records were destroyed by fire at the Custom House.

About this time the returns were made in imperial gallons, the old measures being abolished.

Years.	Imperial Gallons.
1823	6,676,355
1824	6,637,506
1825	10,892,033
1826	7,586,937
1827	7,950,961
1828	9,637,951
1829	7,618,196
1830	6,879,588
1831	7,116,870
1832	6,018,480
1833	7,443,841
1834	9,766,116
1835	9,039,551
1836	9,406,083
1837	8,033,480
1838	8,518,484
1839	9,909,056
1840	9,311,247
1841	7,708,502
1842	7,216,113
1843	6,807,053
1844	8,584,586
1845	9,469,776
1846	7,711,309
1847	7,938,067
1848	7,536,730
1849	7,970,067
1850	9,304,312
1851	9,008,428
1852	6,793,304
1853	11,029,567
1854	10,875,855
1855	8,946,766
1856	9,474,694
1857	10,336,845
1858	5,791,656

TABLE OF WINE CONSUMPTION.

Wine consumption and proportion to population. Down to the year 1787 the importation and consumption were nearly equal.

Years.	Imperial Gallons.
1787	4,521,941
1788	6,650,644
1789	5,959,098
1790	6,601,038
1791	7,573,790
1792	7,851,707
1793	6,610,701
1794	6,811,374
1795	8,238,438
1796	5,776,260
1797	3,569,261
1798	5,265,768
1799	6,138,164
1800	7,294,752
1801	6,876,710
1802	7,113,416
1803	8,226,464
1804	5,457,691
1805	4,622,701
1806	5,825,178
1807	6,271,346
1808	6,331,875
1809	5,894,177
1810	6,521,293
1811	5,629,722
1812	5,024,530
1813	4,565,477
1814	5,330,774
1815	4,624,105
1816	4,057,038
1817	5,142,829
1818	5,635,216
1819	4,615,212
1820	4,586,495
1821	4,686,885
1822	4,606,999
1823	4,845,060
1824	5,030,091
1825	8,009,542
1826	6,058,443
1827	6,826,361
1828	7,162,376
1829	6,217,652
1830	6,434,445
1831	6,212,264
1832	6,965,542
1833	6,207,770
1834	6,480,544
1835	6,420,342
1836	6,809,212
1837	6,391,531
1838	6,990,271
1839	7,000,486
1840	6,553,922
1841	6,184,960
1842	4,815,222
1843	6,068,987
1844	6,838,684
1845	6,736,131
1846	6,740,316
1847	6,053,847
1848	6,136,547
1849	6,251,862
1850	6,437,222
1851	6,280,653
1852	6,346,061
1853	6,813,830
1854	6,775,858
1855	6,873,601
1856	7.367,874
1857	7,042,042
1858	6,697,146

The wine consumption, with a population of about eight or nine millions in 1787, augmented to nearly twenty millions of souls in 1851, showed little increase, in consequence of the duties on several classes of wines reaching fully to 500 per cent. That the means of purchase increased with the population, is shown by the augmented value of property assessed in 1803 = £115,351,952, and in 1843 = £181,322,202.—*James on the Wine Duties*, 1855. If, with eight or nine millions of souls, we consumed seven millions of imperial gallons, with twenty millions of population we should have consumed double that quantity, in place of no increase having taken place—spirit having been substituted.

	Imperial Gallons.	Population.
1787 to 1792	39,158,218	8,000,000
1793 to 1798	36,871,802	8,500,000
1799 to 1804	41,107,197	10,812,000
1805 to 1810	35,466,570	....
1811 to 1816	29,231,636	13,296,177
1817 to 1822	29,273,636	14,072,331
1823 to 1830 (8 years)	50,583,970	16,000,000
1831 to 1836	37,495,674	16,255,605
1837 to 1842	37,936,392	18,664,761
1843 to 1848	38,574,512	....
1849 to 1854	38,909,486	20,919,531

The consumption of wine was three and a half bottles per head from 1785 to 1794. It fell to three bottles from 1794 to 1814; and from 1814 to 1820 to two bottles. After that one and three-tenths bottle per head.

From 1786 to 1794 the Portuguese wine consumed in Great Britain, principally port, was 75·67 per cent., because there were only two-thirds of the duty paid upon the wines of Portugal that were paid on other wines. The duties were equalized in 1831, and from that time to 1854 the consumption of port diminished, until, in 1854, it was only 36·69 of the whole consumption. Spanish wines, only 16·67 in the first period, rose to 38·34 per cent.; French wines that were only 3·26 per cent., had risen in 1854 to 8·12.

Table of the proportions of different wines consumed in England, for which the Editor is indebted to Mr. JAMES, author of the *Wine Duties considered Financially and Socially, et cetera*, 1855:—

TABLE OF PROPORTIONAL CONSUMPTION.

Years	Colonial. Per cent.	Spanish Per cent	Portuguese Per cent.	French. Per cent.	Sicilian. Per cent.	Madeira. Per cent.
1849	3·87	39·16	42·36	5·03	7·11	1·14
1850	3·82	38·36	43·73	5·29	6·61	1·09
1851	3·74	40·33	40·02	7·12	6·28	1·10
1852	3·82	41·08	39·23	7·05	6·12	1·1
1853	3·92	39·58	38·87	7·79	7·55	1·02
1854	3·75	38·33	36·67	8·15	11·32	0·06
1855	3·95	40·42	35·16	7·99	10·82	0·05
1856	4·02	39·81	34·03	8·33	10·43	0·57
1857	6 05	39·43	32·72	8·83	10·62	0·05
1858	10·89	39·67	28·69	8·54	10·33	0·05

Proportion of White to Red Wines consumed.			*Cape import at half duty.*	*Cape consumption.*
Years.	White.	Red.	Imperial Gallons	Imperial Gallons.
1854	52·065	47·935		
1855	54·32	45·68	361,605	261,564
1856	54·31	45·69	492,087	352,330
1857	54·85	45·15	787,753	456,214
1858	59·21	40·79	654,118	726,314

DECREASE IN IMPORTATION, 1858, COMPARED WITH THE PREVIOUS YEAR.

Total.	Pipes.	Decrease. Pipes.	
French imports	1,742	504	
Portuguese imports	14,240	3,332	
Spanish imports	20,078	1,114	
Sicilian imports	1,900	114	
Madeira and Canary	192	52	
From Holland	79	32	
Other places	2,339	401	
British Possessions	1,427	..	
Total	41,997	5,549	
		2,950	Colonial increase at half-duty deducted.
		2,599	Decrease.
		58	Decrease mixed in bond.
Total		2,657	Pipes decreased.

The Cape wines at half duty increased in ten years, from 3·87 to 10·89. Spanish were stationary, or with a small increase. Portuguese decreased from 42·36 to 28·69. Other wines, except Madeira, increased.

In the monetary provisions of the government for 1860, the duties were reduced upon all wines of all countries and of our own colonies from five shillings and sixpence and five per cent., to take place on January 1, 1861, on wines of the lowest alcoholic strength, or not above 18°. These to be admitted at one shilling per gallon. The wines above this alcoholic strength at two shillings, or wines approaching 40° of proof spirit. This reduction to commence at first by a fall of duty to three shillings per gallon, from the existing five shillings and sixpence $\frac{2}{20}$.

The grocers' home made wines, free of duty, aided to supersede foreign wines in consumption, and thus injured the exchange of goods with the foreigner; these wines or compounds having been sold at little more than the duty ouly on foreign wines.

The average product of wine in France is nine hundred millions of gallons; and in Paris two hundred and sixteen bottles per head are annually consumed; in Hamburg twenty-nine per head. The following table is the most authentic extant, and there is reason to think much within the real limit of the produce of the wines of Europe:—

	Gallons.
France	900,000,000
Hungary and Austria	500,000,000
Spain	220,000,000
Italy	195,000,000
German States, Prussia, Luxemburg, &c.	45,000,000
Portugal—total product	10,500,000
Sicily	3,000,000
The Azores	575,000
The Canaries	1,875,000
Cape of Good Hope 14,000 leaguers of 60 gallons	840,000
Cyprus, Commandery, Muscadines, &c.	30,000
Servia, Wallachia, &c.	170,000
Total	1,876,990,000

Greece produces four millions six hundred and forty thousand okes; Asia Minor, Syria, Palestine, Persia, and the East produce wine, as well as some parts of Southern Russia.

The following tables, from *Redding on Wines*, contain a selection out of a number of the fine growths, of the names and character of the wines produced in the principal countries in Europe. To extend the list would be useless. In France alone, there are six classes of red wine, seven of white, and five of *vins de liqueur*. There are four hundred and sixty-three red wines, two hundred and forty-three white, and nine *de liqueur*. The champagne wines alone reckon six degrees in quality:—

WINES OF THE FIRST CLASS.

FRANCE, SPAIN, HUNGARY, GERMANY, SICILY, NAPLES, AND CAPE OF GOOD HOPE.

Wines.	Country.	Place	Character.
Romanée Conti	France	Côte d'Or	The first and most delicate red wines in the world, full of rich perfume, of exquisite bouquet and fine purple color; light, yet with body and spirit sufficient to render them pleasant and healthful in use.
Chambertin	“	“	
Richebourg	“	“	
Clos Vougeot	“	“	
Romanée St. Vivant	“	“	
La Tache	“	“	
St. Georges	“	“	
Corton	“	“	
First growths of Prémaux	“	“	Burgundies, closely resembling the above growths in aroma, and all their other qualities.
Musigny	“	“	
Clos du Tart	“	“	
St. Jean	“	“	
Perrière	“	“	
Veroilles	“	“	
Morgeot	“	“	
Mont Rachet	“	“	White, highly esteemed.
Lafitte	“	Gironde	Fine color and perfume, light, less warm than Burgundy, with a taste of the violet, and a rich purple hue.
Latour	“	“	
Château Margaux	“	“	
Haut Brion	“	“	
Beaume	“	La Drôme	Wines of the Rhône, darker in color than the preceding. Red Hermitage the most noted of these, of good body, and a fine flavor of the raspberry.
Muret	“	“	
Bessas, Burges, Landes	“	“	
Méal and Gréfieux	“	“	
Racoule, Guionière	“	“	
Sillery	“	Marne	White, still, dry; of an amber color; generally iced for drinking.
Ay	“	“	Fine effervescing wine, bright in color, slightly frothing.
Mareuil	“	“	The best of the white wines of Champagne, being all of the first quality, but differing a little in color and effervescence.
Hautvilliers	“	“	
Pierry	“	“	
Dizy	“	“	
Epernay—Closet	“	“	
St. Bris	“	Gironde	Fine white wines of excellent quality, lightish brown in color, aroma most agreeable, and some of rather sweet taste.
Carbonnieux	“	“	
Pontac	“	“	
Sauterne	“	“	
Barsac	“	“	
Preignac and Beaumes	“	“	Description resembles the preceding.
Château Grillet	“	La Loire	
Hermitage	“	Rhône	Full of body, spirit, and perfume. The white is the finest of all white wines.
Rivesaltes	“	Pyrénées Orientales	A rich muscadine.
Colmar, Olwiller, Kaiserberg	“	Haut Rhin	Straw wines, rich and luscious.
Kientzheim, Ammerschwir.	“	“	Ditto.
Hermitage de Paille	“	Rhône	Ditto.
Amontillado Sherry	Spain	Andalusia	A dry delicate wine.
Schloss Johannisberger	Germany	The Rhine	Ditto.
Lacryma Christi	Naples	Naples	A fine, luscious, sweet red wine.
Syracuse	Sicily	Syracuse	Remarkably fine red muscat.
Tokay Essence, and its first growths, called Tarczal, Szeghi, Zadany, Tolesva, also Erdo-Benye, Zambor, Tallya, Mada	Hungary	County of Zemplin	Thick rich wines, known as Tokay, also Tokay-ausbruch.
Cotnar	Moldavia	Cotnar	Very spirituous, by some preferred to Tokay. Greenish color.
The Commandery	Cyprus	Com. D.	Thick, rich, and luscious.
Constantia	Africa	Cape of Good Hope	Luscious; two kinds.
Lagrimas	Spain	Malaga	Thick and luscious.

SECOND CLASS.—French.

Wines.	Place.	Character
Verzy, Verzenay, Mailly, St. Basle, Bouzy, St. Thierry	Marne	Red wines of Champagne.
Vosne, Nuits, Chambolle, Volnay, Pomard, Beaune, Morey, Savigny, Meursalt	Côte d'Or	Excellent red Burgundies, very little inferior to first growths.
Olivotes, Pitoy, Perrière, Préaux	Yonne	Good wines.
Chainètte, Migrenne	“	

SECOND CLASS.—FRENCH.—(*Continued.*)

Wines.	Place.	Character.
Moulin à Vent, Torins, Chénas.....	Saone et Loire, Rhône	Red.
Hermitage, second growths........	Rhône	Red.
Côte Rôtie........................	"	Red.
Rozan, Gorze, Léoville, Larose, Branne-Mouton, Pichon-Longueville, Calon...................	Gironde	Red.
Côteau Brûlé.......................	Vaucluse	Red.
Jurançon, Gan.....................	Basses Pyrénées	Red.
Roussillon, Bagnols, Cosperon, Collioure, Torémila, Terrats, Masdeu..........................	Pyrénées Orientales	Red.
Cramants, Avize, Oger, Menil......	Marne	White Champagne wines, of good quality.
La Perrière, Combotte, Goutte d'Or, Genevrière, Charmes et Meursalt	Côte d'Or	White Burgundies, of high repute in France.
Guebwillers, Turkeim, Wolxheim, Molsheim, and Rangen, in Belfont	Haut Rhin Bas Rhin	Dry, white, and *vins de paille*, of good repute.
Arbois, Papillin, Château Chalons..	Jura	Good wine, *mousseux* and still.
Coudrieu..............	Rhône	A white wine, which keeps long, of fine *sève* and perfume.
Langon, Cerons, Podensac.........	Gironde	White wines, capable of endurance.
Montbazillac, Tcaulet, Raulis, Suma, Sancé...................	Dordogne	Good white wines of the country.
Buzet, Amazon, Vianne...........	Lot et Garonne	Generous white wines, of good body.
St. Peray, St. Jean...............	Ardèche	Delicate *mousseux* and *non mousseux*, of agreeable flavor.
Jurançon.........................	Basses Pyrénées	White, with an agreeable perfume of the truffle.
Frontignan and Lunel Mazet.......	Herault	Sweet, rich, and luscious; white.
Bagnols, Collioure, Rodez..........	Pyrénées Orientales	Red, styled *de Grenache*, rich and sweet.
Maccabeo of Salces...............	"	Sweet, *vins de liqueur.*

THIRD CLASS.—FRENCH.

Wines	Place	Character
Hautvilliers, Mareuil, Dizy, Pierry, Epernay, Taisy, Ludes, Chigny, Villiers-Allerand, Cumiéres....	Marne	Red Champagne wines of the second quality; light and agreeable.
Ricey, Avirey, Bagueux la Fosse....	Aube	Resembling the preceding.
Gevrey, Chassagne, Aloxe.		
Savigny sous Beaune, Blagny, Santenay, Chenôve..	Côte d'Or	Good Burgundies of the third quality.
Clarion, Bouvin...................	Yonne	Ditto.
Fleury, Romanéche.		
Chapelle Guinchay................	Saone et Loire	Ditto.
Chantergues, Montjuset...........	Puy de Dome	Not wines of note; red.
Crozes, Mercurol, Gervant.........	Drome	Resembling red Hermitage; a little less full and fine, might be called Hermitage of the third quality.
Seyssuel, Revantin................	Isère	Red wines, very middling of the class.
Verinay..........................	Rhone	Resembling Cote Rotie.
Pouillac, Margaux, Pessac, St. Estephe, St. Julien, Castelneau de Mèdoc, Cantenac, Talence, Merignac, Canon	Gironde.	Pouillac, St. Estephe, good light red wines; Castelnau mediocre; the other growths agreeable.
Farcies, Terrasse, Campreal........	Dordogne	Resembling St. Emilion; keeping well.
Cape Breton, Soustons............	Landes	Red; light colored, with a harsh taste.
Chuzelan, Tavel, St. Genies, Virac. Ledenon, St. Laurent des Arbres	Gard	Red wines, grown on the banks of the Rhone; will not keep good more than six years.
Chateauneuf......................	Vaucluse	Good red wines; keep well.
Riceys...........................	Aube	Champagne; light and agreeable, white.
Rougeot de Meursalt..............	Côte d'Or	Tolerable wine; not exported.
Vaumorillon, Grises, Valmure, Grenouille, Vaudesir, Bourgereau, Mont de Milieu et Chablis..	Yonne	In considerable esteem in Paris as wines of the table. They are all white.
Pouilly and Fuissé................	Saone et Loire	Much the same as the preceding.
Etoile, Quintignil................	Jura	White.
Pujois, Ilats, Landiras, Virelade St. Croix du Mont, Loupiac....	Gironde	White; of middling quality.
St. Michel sous Condrieu..........	Loire	White; consumed in the country.
Frontignan and Lunel.............	Herault	Second growths of those famous and rich white wines.
Vins de Picardan of Marseillan and Pommerols. Vins de Calabria, de Malaga..............	"	Rich luscious sweet wines, prepared in the department of Herault, and very little exported; also muscadines.
Roquevaire, Cassis, Ciotat. Vins Cuits..........................	Bouches du Rhone	Rich sweet wines, boiled wines, and malmseys, of good quality.

SECOND AND THIRD CLASSES.—GERMAN.

RHINE AND MOSELLE.

Wines.	Place.	Character.
Johannisberger	Johannisberg	Grown near the Schloss Johannisberger, in the list of first growths already given.
Steinberger	Rheingau	A very fine growth.
Rüdesheimer Berg Hinterhaüser	Rheingau, six leagues from Mayence, facing Bingen; on the hill and slope behind the houses.	
Laubenheimer	Mayence district	Lighter than Johannisberger; fine bouquet.
Kœsterich	"	A highly prized wine.
Niersteiner	"	Lighter than Johannisberger, but delicate.
Oestricher	"	Ditto.
Liebfrauenmilch	Worms	A good wine, with fine flavor and body.
Zornheimer	The Rhine	Ditto.
Hochheimer	Spire, on the River Mayn	Hence the word hoch. The first growth is the prime hoch wine of the importer. Light, agreeable—12·08, average of spirit. Some kinds, when new, contain as much as 14·37, according to BRANDE.
Graefenberger	Rheingau	Choice wine, of fine flavor.
Gaubischeimer	Near Mayence, the palatinate	Light, agreeable, good bouquet.
Deidesheimer	"	An excellent wine.
Oppenbeimer	"	Ditto.
Bodenheimer	"	An excellent wine, light and delicate.
Nackenheimer	"	Ditto.
Brauenberger	Moselle, Treves district	Of first quality.
Scharzberger	"	Ditto.
Graach	"	Ditto.
Zettingen	"	Ditto.
Wehlen	"	Ditto.
Piesport	"	Ditto.
Montagne Vert	"	Second quality.
Causel and Valdrach	"	Moselle, noted for diuretic qualities.
Rinsport	Moselle, Witlich canton	Secondary Moselle.
Bacharach	Near Mayence	Wine once in high repute.
Becherbach	Becherbach canton	Secondary Moselle.
Walporzheimer	Upon the Ahr	Called wine of the Ahr.
Rutz	On the Moselle	Considered one of the Moselle wines.
Steeg	Near Bacharach	A light Rhine wine.
Montzingen	"	Inferior light Rhine wine.
Bodendorf	Near Bonn	A secondary wine.
Affenbourg Hamen	Near Coblentz	Ditto, a Rhine wine.
Strang	Near Neider Breisig	Ditto.
Elzenburger	"	Ditto.
Alzenburger	"	Ditto.
Lutz	Near Treiss	Ditto.
Maas and Huhn	Niedar Heimbach	Ditto.
Stugerboeg	Rhine	Ditto.
Engehohe	On the Nahe	Called wine of the Nahe; secondary wines.
Neiderborg	"	Ditto.
Leinenborn	"	Ditto.
Bangert	"	Ditto.
Rosenhech	"	Ditto.
Rensberger	Tarbach	Secondary Moselle.
Wurzgarten	Tarben	Ditto.
Amfuhr	Burg, left bank of the Rhine	Ditto.
Rothenberger	Geisenheim	Soft, delicate, prime wine.
Scharlach	Mt. Scharlachberg	Fine flavored; rich aroma.
Roth	Near Hochheim, Spire district	Hoch of good quality.
Konigsbach	"	Ditto.
Weinheim	"	Ditto.
Forst	"	Ditto.
Ungstein	"	Ditto.
Schierstein and Narden	Wisbaden	Tolerable wines.
Epstein	Near Frankfort	Middling wines.
Phillipsech	"	Ditto.
Reichenberger and Wildenstein	Erbach	Inferior Rhine wine in quality.
Fènerbach and Laufen	Near Fribourg, at Badenweiler	These are considered the best wines of Baden.
Heidelberger and Kleingenberger	Baden	Good wines of the country.
Richenau Island	Lake of Constance	Ditto.

SECOND AND THIRD CLASSES.—GERMAN.—(*Continued.*)

RHINE AND MOSELLE.

Wines.	Place.	Character.
Meresberg and Uberlingen........	Near the Lake	Good wines of the country.
Cretzingen........................	Baden	Ditto.
Berghausen and Stellingen	"	Ditto.
Beringfield and Zeil..............	Bavaria	Inferior wine.
Lindau and Ravensburg.............	"	
Schweinfurt.......................	"	
Liest.............................	Würtsberg	Excellent wine, Rhenish character.
Stein.............................	"	Ditto, of a very dear price.
La Harpe	"	Inferior, but often sold for Stein.
Escherndorf and Schalhsberg.......	"	Inferior to Stein.
Bischofsheim	Near Hanau, Frankfort	A tolerable wine, resembling Rhenish.
Calmus	Trieffenstein, near Aschaffenbourg	A *vin de liqueur*.
Guben	Saxony	Very poor wines.
Meissen		
Franconia.........................	Franconia	A *vin de paille;* aromatic.
Assmannshäuser	Rheingau, near Rüdesheim	Equal to the second class of Burgundy ; excellent body.
Bessingheimer.....................	Lauffen, Wirtemberg	Well tasted, good bouquet ; called wine of the Neckar.
Altenahr..........................	Rhine country, left bank	Inferior wines.
Mayschof..........................	"	Ditto.
Rech..............................	"	Ditto.
Ahrweiler	"	Ditto.
Bruch	"	Ditto.
Creutzberger	"	Ditto.
Hoënningen	"	Ditto.
Kesseling	"	Ditto.
Dernan	"	Ditto.
Blischert.........................	Lintz	A tolerably good wine.
Neuwied Blischert.................	Hesse Darmstadt	Ditto.
Wangen	Bavaria	Poor, though esteemed in the country.
Naumbourg	Saxony	Like fourth class Burgundy ; styled *vins agrelets.*
The wine of Blood, Sang des Suisses	Bale	A good wine, called also the Hospital and Cemetery of St. James.
Erlach............................	Berne	
Valteline.........................	Made in the Valteline	Remarkable for durability.
Boudry and Cortaillods............	Neufchâtel	Equal to third class Burgundy.
Cully	Near Lausanne, and Vevay	Like Rhenish.
Désalés...........................		
La Cote	Between Lausanne and Coppet	Dry wines.
Bernang...........................	St. Gall	Tolerable of the country.
Frangy and Monnetier..............	Geneva	
La Marque	Martigny	Red and white, and muscadine of tolerable quality.
Coquempin		
Chiavenna	Grisons	Aromatic, white, from red grapes.

SECOND AND THIRD CLASSES.

PORTUGUESE.

Wines.	Place.	Character.
Carcavellos, or Lisbon............	Between Œiras and Carcavellos	Sweetish, white, well known in England.
Bucellas..........................	Near Lisbon	A fiery wine, from brandy being mixed with it; something like Barsac when pure.
Vinho de Termo	Estremadura	A light ordinary wine of the country.
Setuval	"	Two kinds, dry and muscadine ; both good.
Lamego	Near Coimbra	An inferior kind of Bordeaux.
Alenquer, Monçaon.................	Estremadura	As the former, but somewhat better in quality.
Santorin..........................	Near Lisbon	An ordinary wine.
Barra a Barra.....................	Near Lavadrio	A good wine.
Colares	Near Cintra	A light port, of good quality.
Pezo da Regoa, Abasas, Villarinho des Freires, Gorvaens, Alvacoês, do Corgo, Hormida, Guials, Convelinhas, Galafura, Lavradrio...	Mostly on the Douro	Port wines of the Douro, of the first and second qualities, denominated Feitoria and Ramo.

SECOND AND THIRD CLASSES.

ITALIAN AND SICILIAN.

Wines.	Place.	Character.
Lacryma Christi	Naples, Mt. Vesuvius	Red rich muscadine, of a fine flavor and perfume.
Syracuse	Sicily	Luscious red muscadine.
Reggio	Naples	Resembling Burgundy.
Baia	"	Ordinary wine.
Mascoli Mascoli Sciarra Mascoli Macchia Mascoli San Giovanni	Sicily, Mt. Etna	The best red wines in the island, of excellent body, like the secondary Rhone growths; rare in the island.
Catania	"	Pitchy taste, ordinary smell.
Tormina and Faro	"	Tolerably good.
Oviěto	Roman States	Excellent durable red wines.
Asti	Piedmont	Ditto.
Bianillo and Aleatico	Elba	Good wine of the second class.
Bischillato	"	A durable wine, exports well.
Procanico	"	A *mousseux* wine.
Chianti	Tuscany	A good wine.
Aleatico	"	Resembling the Tinto of Alicant in flavor and bouquet.
Carmignano, Antella, Artiminio, Tizzana, Mentali, Lamporecchio, Monte Spertoli, Poncina, Glogoli	"	Good wines of the country.
Val di Marini	"	Ditto.
Naples muscadine	Mt. Vesuvius Lake Averno Maria de Capona	A delicate fine colored wine.
Vino Greco	"	An excellent muscadine.
Carigliano	Naples	Muscadine, flavor of fennel.
Bari and Tarento	"	Muscadine and common.
Reggio	"	*Vin de liqueur.*
Baia	"	Good ordinary wine.
Gierace	Near Reggio	Between light French wine and *vin cuit.*
Asprino	Campagna	A *vin de mousseux.*
Fundi	Kingdom of Naples	Good ordinary wine.
Val di Mazara Mazara Veterano Corigliono Termini Girgenti	Sicily	Of tolerable quality.
Messina, Milazzo, Avola, Vittoria	"	Ditto.
Lipari and Stromboli	Lipari Isles	Ordinary wines, and superior muscadine.
Imola	Near Bologna	*Vin cuit* and *mousseux.*
Terni	Near Spoleto	Good wines.
Farnese	Near Castri	Good muscadine.
Oviěto (white)	Roman States	Muscadine, not durable.
Monte Fiascone	Near the Lago Bolsena	A strong muscadine, finely perfumed and flavored; of great strength.
Albauo	Roman States	Ditto, excellent.
Moscatello Aleatico Vino Santo Vernaccia	"	*Vins de liqueur*, of greater or less merit; not bearing exportation.
Riccia	"	Good wine, but a small quantity made.
Buti	Plain of Pisa	Weak wine.
Monte Pulciano	Tuscany	The most esteemed of the Tuscan muscadines.
Montalcino, Rimeneze, Pont-Ecole and Santo Stephano	"	Good muscadines.
Vermut	Elba	A cordial wine, prepared with wormwood, &c.
Rio	"	Good muscadine.
Vino Morto	The Veronese	Deficient in spirit and strength.
Vino Santo	"	Good red and white wines.
Bellagio	Lake of Como	Wines of color and spirit.
Labusca	Mantua	An agreeable wine.
Pavia	Pavia	Both dry and *mousseux*, but very inferior wines.
Moute di Brianza	Milan	Good flavored wines.
Panocchia, Vigatto, Traversetolo, Casola, Avola, Azano	Parma	Ordinary wines of the country.
Val Irdone, Bottola, Ponté d'Allolio, Verdetto, Sala del Christo Creta	Placentia	Ditto.
Santo Pretasso, Frescale, Caselle, Lassurasco, Rugarlo, Castellina, Salso, Maggiore, Villa-Chiara, Claretto, Pazolo	District of Borgo Placentia	Inferior wines, some of them *vins de liqueur*, having a disagreeable taste of honey.
Ratrera and Sapolo	Modena	Ordinary wine, for home consumption.
Vin Piccolit	Friuli	Resembling Tokay.

SECOND AND THIRD CLASSES.

HUNGARIAN, AUSTRIAN, AND SCLAVONIAN.

Wines.	Place	Character.
Tokay, Essence, and Ausbruch	Near Mt. Tokay, Hungary	See wines of first class.
Tokay, Maslas	"	A secondary Tokay.
Gyæugyæsch	Mount Matra, Upper Hungary	Wines, both red and white, much esteemed.
Œdenbourg	Lower Hungary	Ditto.
Meneser	District of Arad	Red, much esteemed for spirit and sweetness.
Meneser-Ausbruch	"	Like Tokay, preferred by some; rich, aromatic, sweet, not cloying.
Erlon	Upper Hungary	Good red and white wines, and an Ausbruch.
Rusth	Lower Hungary	Similar to Œdenbourg.
St. Gyorgy	Near Presburg	A white wine of excellent quality, somewhat in aroma like Tokay.
Ofen	Near Pesth	Good wine of the country.
Carlowitz	On the Danube, in Sclavonia	Resembles Cote Rotie.
Buda	Near the ancient capital	Like Burgundy.
Sexard	Between Buda and Esseh	Resembles Languedoc, a good red wine of the country.
Gros Warden	Near Transylvania, the fortress	Ditto.
Schiller	In Sirmian	Strong and sweet, of a red color.
Wermuth Palunia Tropfwermuth	"	Wines prepared with spices and wormwood.
Glodova, Menos, Gyordk, Paulis	Menes	Scarcely different from Meneser.
Modeon	Near Presburg	Excellent wine, resembling Burgundy.
Katschdorf, Grunau, Obernusdorf	"	Ditto.
Neustoed, Zschelhæ, Kosrad	Near Buda	Wines like Burgundy and Bordeaux.
Wersitz Jobbagy, Etsey, Sœtvesch	In the Bannat	
Weisskirchen	Bannat of Tameswar	Good red wine.
Zips, Arva, Liplow	"	Ditto.
Buokwetz	Croatia	White wine.
Vinitza, Toeplitz	"	Ditto; same quality.
Birthalman	Transylvania	Wine of the country, Ausbruch.
Marachina	Sebenico, Dalmatia	A wine highly characterized; not the *liqueur*.
Cotnar	Moldavia	Green in color, and strong as brandy.
Piatra	Wallachia	Light, rivalling Tokay.
Gravosa	Ragusa	Good country wine.
Semlin	Sclavonia	Good red wine.
Syrmia and Posega	"	Both red, and of agreeable flavor, and much spirit.
Podskalchi	Circle of Leutmeritz, Bohemia	Red wines, which will not keep.
Melnick	Circle of Bunzlow	Ditto, like Burgundy.
Poleschowitz	Moravia	Good wines, equal to Hungarian.
Mount Calenberg	Austria	Ordinary wine.
Hoeflein, Kloster Newbourg, Unter Kutzendorf, Kaplenburg, Misdorf, Salnendorf, and Lichtenstein	"	Wines of little note, generally of a green hue, and drank young.
Giberwein	Southerly, near Vienna	A wine that will keep, though of no extraordinary quality.
Spitz	"	Good wine.
Luttenberg	Lower Styria	Good wines, red and white.
Radskersbourg, Arnfels, Windisch, Gonowitz, Kerchenberg	"	Of the next rank to the foregoing.
Sansal, Leitschach, Pickerne, Stadlberg, Pulsgau, Sauritsch, Raen, Rast, Peittersberg, Wiesel	"	Good wines of the country.
Moettling, Weinitz	Carinthia	Resembling good Italian wines.
Freyenthurn, Wipach, Tscheremble, Marzamin	"	Ditto.
Proseco Antignana, St. Serf Trieste	Istria	Red and white, sparkling and well flavored.
Berchetz	An Adriatic island	Red wine, deep colored and sweet.
St. Patronio, Petit Tokai, St. Thomas, &c	At Capo d'Istria, Pirano, and Cittanova	Good *vins de liqueur*.
Corregliano	Istria	A good wine, consumed at Venice.
Izeszgard	In the Tolna district	A superior red wine.

SECOND AND THIRD CLASSES.—SPANISH.

Wines.	Place	Character.
Val de Peñas	New Castile	Good body, deeper than Bordeaux in color.
Manzanares	Manzanares	An inferior Val de Peñas.
Ciudad Real	New Castile	A tolerable red wine.
Albacete	"	Ditto.
Vino Tinto, Alicant	Valentia	Yellowish red color, when old called Fondellol.
Mataro	Catalonia	Good bodied and generous.
Torre, Beni Carlos, Santo Domingo, Segorbe, Perales, Vineroz	Valentia	Wines of good body, some of the most esteemed red growths of the country; color deep.
Hospital	Arragon	Excellent flavor and body, from the Garnacho grape.
Carignena	"	A vino tinto from the same fruit.
Tinto Olivencia	Estremadura	Excellent red wine, the best in Spain.
Tinto di Rota, or Tintilla	Andalusia	A sweet reddish cordial wine.
Ribidavia	Gallicia	An ordinary red wine.
Chacoli	Biscay	A very harsh austere wine.
Guindre	Malaga	Dark, flavored with cherries.
Tinto di Malaga	"	Seldom exported, a good wine.
Aleyor	Minorca, near Mount Taurus	A red wine, consumed on the island.
Palma	Majorca	A full-bodied wine.
Cordova	Andalusia	Good red wines of the country.
Mirando de Ebro	Old Castile	
Carbezon	Valladolid	
Terra del Campo	Old Castile	
Velez Malaga	Malaga	A luscious sweet wine.
Malaga	"	A luscious sweet wine, with a burnt taste.
Pedro Ximenes	"	A luscious sweet wine, fine and delicate.
Malaga Xeres	"	Resembling sherry, dry.
Xeres vino seco, pale and brown	Xeres de la Frontera	Pale and brown sherry.
Abocado	"	A second growth sherry.
Huesca	"	A yellowish-white wine.
Paxarete	Frontera and St. Lucar	A sweet wine, of light amber color.
Moguer	Niebla, Andalusia	Used to lower the sherries at Xeres, of which it is an inferior species.
Negro Rancio	Rota	A sweet wine, of a yellow color.
Montilla	Cordova	A dry wine, of good bouquet and flavor.
Borja	Arragon and Tarragona	A luscious wine.
San Lucar di Barameda	Andalusia	A light red muscadine.
Manzanilla	"	Dry white, of inferior quality; a *vin du pays*.
Zalonge and Carlon	"	Ditto.
Yepes	New Castile	A well-flavored wine.
Fuençeral	"	A *vin de liqueur*.
Sitges and the Priory	Catalonia	Malmseys of two qualities.
Peralta and Tudela	Navarre	White dessert wines. Peralta is a Rancio when aged.
Pollentia	Majorca	A *vin de liqueur*.
Alba Flora	Minorca	A dry kind of Rhenish.
Vidonia	The Canaries	A wine resembling Madeira, of inferior quality.
Verdona	"	A green wine, not now made.
Palma	"	A rich Malmsey, having a taste of the pine apple.

MADEIRA AND THE AZORES.

Wines	Place.	Character.
Malvasia, or Malmsey	Madeira	Rich and sweet.
Madeira	"	A durable, dry wine.
Sercial	"	Ditto, of excellent quality.
Muscatel	"	Not exported: a good wine.
Tinto	"	A red wine, changing in twenty years to rich old Madeira in color.
Figaa do Pereiro	"	Of inferior kind to the above.
Santo Antonio	"	
Vino Passado	Pico, in the Azores	A species of Malmsey, of light quality; keeps ill.
Vino Seco	"	A dry wine, light, not durable.

DOMESTIC WINES.—The grape ripens too seldom in England to be applied with advantage to the making of wine. The warmth of September is not sufficient to mature the grape; though up to some time in August, and generally to the end of that month, the vine may progress favorably. There are many fruits, however, from which very palatable household wines can be made, and from which dull wines are continually manufactured, when those more lively can be introduced from the produce of the orchards, gardens, and fields of England. The mode of making these wines is generally not well understood; if it were, the wines would be much more palatable. Yeast, resorted to for the purpose of fermentation, often imparts a nauseous after-taste to the wine, which would ferment well enough in the natural way. There is nothing unwholesome in these wines, if properly made; and to this end the wine of the grape, and its mode of management, should be clearly comprehended, that its principles may be made applicable to domestic wine manufacture. The malic acid in the wines of English fruit often causes a trifling inconvenience to the *primæ viæ*, which acid may easily be exterminated in making the wine. The wine of the grape should be the model after which all wine of the garden-growth should be fermented—general principles should be first mastered. Suppose the gooseberry be taken as the fruit, it contains centesimally:—

	Unripe.	Ripe.
Green coloring matter,	0·03	—
Sugar,	0·52	6·24
Gum,	1·36	0·78
Albumen,	1·07	0·87
Malic acid,	1·80	2·41
Citric acid,	0·12	0·30
Lime,	0·24	0·29
Lignin, with seeds,	8·45	8·01
Water,	86·41	81·10
	100·00	100·00

The above are all the requisites for making wine, and some that are to be dispensed with; a deficiency in tartar is often noticed, but this can be supplied artificially. The excess of malic acid, on the other hand, is injurious; but as in making white wines in the South of Spain, this acid is got rid of by sprinkling powdered gypsum over the grapes, which takes it up, the same means should be adopted when making domestic wines in England.

Sugar is the first constituent in wine-making, and as it does not abound in some garden-fruits in England, it must be added. Cane-sugar, it has been seen, differs from grape-sugar in its proportional parts, but it is converted into grape-sugar by the process of fermentation. It is a sugar which goes slower into fermentation than that of the grape, and the alcohol in the wine always bears a proportion to the pre-existent sugar. This sugar uniformly contains a portion of a vegetal extractive matter, unless it is separated from it by art. The natural sugar of some plants also contains, some more, others less, of this sweet vegetal matter. If there is much of it in the sugar, the wine will be dry and perfect, because all the sugar will have been changed into alcohol. The mucilage, or vegetal extractive matter, like the gluten of wheat or albumen, contains azote, the gas of which has been noticed in grape wine making. This matter, found too in yeast, thus acts in exciting fermentation. Most garden fruits possess it; and it is this sweet principle combined with that in sugar, which operates the conversion with other wine, as with the grape. Water is another constituent. As to the other substances, except tartar, they rather concern the curious in chemistry than the maker of family wines, for some can only be detected by the close scrutiny of the experienced chemist. Little color can be communicated to any of our domestic wines, if the elderberry, currant, blackberry, and black cherry be excepted; but this is a matter of little moment in that which should rather be adopted to please the palate than the eye. If astringency or roughness be in request, that loss may be innocently supplied by the application of catechu. The damson and sloe alone possess it naturally.

The substances necessary to vinous fermentation, the sugar and its sweet principle, the natural vegetal extract, the tartaric acid—in place of which latter the malic acid is often found, which should be dispensed with, and tartar added artificially—and water; these in certain preparations, and in their differences, are the essentials in this class of wines. Sugar is the most important, and its decomposition gives out the alcohol, on which the strength of the wine depends; therefore its quality is of great importance. When the sweet principle and sugar—for they are in union—have disappeared in fermentation, and there is no more vegetal extractive matter belonging to the fruit in the liquid, the wine is a dry wine, and is in its perfect state. If the sugar be in excess, the result is wine and sugar; vulgarly, a sweet wine. If the vegetal extract be in excess, and the fermentation too prolonged, acetic acid will be the product.

The want of attention to the foregoing points often renders the making of dry wines a failure. No yeast should ever be used. If the vegetal extractive matter be wanting, the lees of other wine may be tried; but this is seldom needful, with due care. During fermentation the leaven or ferment is insoluble, and rises to the surface, or falls to the bottom. On restoring this to the surface, the fermentation may be prolonged at pleasure, until the necessary dryness be gained. To attain a sweet wine, the fermentation should be stayed by separating the wine from the ferment, and fining it with isinglass or white of egg. Thus the ferment is separated, and the operation suspended; it may be renewed by restoring the separated matter; if not, a sweet wine remains. It cannot run into acetous fermentation if its leaven be expended; but still there is hazard, and some care necessary, in thus renewing the operation.

Of these acids, sometimes found in fruits—the tartaric, malic, and oxalic—only the first two have any share in the fermentation. Tartar abounds in the grape, and to that its superiority is ascribed. It is wanting in our domestic fruits, or very scantily bestowed. Malic acid is predominant in apples and pears, and they give liquors very different from wine. Crude tartar is best added to the must for domestic wines, not the purified salt.

Care should be taken not to carry on fermentation in new wooden vessels, nor to place wine in them without due preparation. The vegetal extract in the wood will infallibly set the fluid in fermentation, as is well known to the French wine-grower.

The end of the fermentation is the production of the alcohol; and the chemical action involved is well understood, although the primary force of the ferment is not, nor can it be, so well comprehended. In this respect Nature eludes the efforts of the chemist and physiologist to define correctly her workings, or submit a true definition of the affinities which are continually set in motion by natural force. As regards fermentation, it is true that only the salient points of the chemical changes are understood, but they are sufficient to govern the industry of the fermentation of liquids of every kind, provided all that chemistry has revealed be known to the operator. In domestic wines no just rule has been regarded. Most of the directions are based upon false principles, and display extraordinary ignorance, according to Dr. M‘Culloch, who has written so well upon the subject; and if not clear to the family makers of such wines, and too scientific for the common concocters of them, his work still is not the less worthy because the stolid do not perceive its merits.

Brande made analyses of the strength of some of the domestic wines, which are appended. The alcoholic strength was per cent. at eighty-nine alcohol and eleven water.

Wines	Per cent.	Wines.	Per cent
Grape,	18·11	Orange,	11·26
Raisin,	26·40	Elder,	8·79
Do.	25·27	Mead,	7·32
Do.	23·20	Cider,	9·87
Do. average,	25·12	Do.	5·21
Currant,	20·55	Do. average,	7·54
Gooseberry,	11·84	Perry, average,	7·26

Before going into the practical part of the subject, the warning against the use of yeast must be repeated. It is a vile substance when in contact with anything vinous, imparting a base flavor, and is to be altogether shunned. The regulation of the temperature, too, is to be sedulously regarded, that the fermentative process may not proceed too rapidly. The bulk of the must to be fermented, and its exact quality must be well considered; the addition of flavoring substances, and finally, the proper vessels adopted for the different operations.

The fruits most commonly employed for making domestic wines are the elderberry, cherry, raspberry, sloe, damson, quince, strawberry, mulberry, gooseberry, lemon, orange, and two or three kinds of currants. Of these several do not retain their flavor, and are to be rejected on that account. The flavor of the strawberry is not communicated to the wine, nor of the quince or raspberry. These might be infused to advantage nearly at the close of the fermentation of some tasteless must, and thus their flavor be sustained in the wine. The blackberry and mulberry should, as in the instance of grape-wine, be allowed to go into fermentation, skins and all, for the sake of the color. The damson and sloe make a good rough wine, but care must be taken to proportion the sugar to the fruit as to quantity, and by protracting the fermentation, to make a dry wine. By a due admixture of elderberries or currants with sloes and damsons, wines like inferior ports are often easily produced. The proportions vary according to the season. The elderberry may be made to yield an excellent red wine. It possesses enough of the extractive principle to impart a very rich tint, and even a fine deep color. Tartar should be introduced into the must; and, besides, this berry requires much sugar, as the saccharine principle is scanty.

The gooseberry is known as giving a species of champagne to the list of domestic wines, which are made to effervesce; but, in order to answer, the gooseberries are used in an unripe state. The effervescing property always results from the use of unripe fruit, and will be readily produced by mixing ripe and unripe grapes together; and it is the same with the gooseberry. In general the flavor is bad, and to avoid it, as it is imparted by the ripe fruit, the more unripe should be prepared. This wine should be made with the expressed juice of the fruit alone, and nothing else should be fermented, the skins not being suffered in the must. By this means any disagreeable or peculiar taste is avoided, and the wine, if nearly tasteless, is brisk, pleasant, and perfectly free from any bad flavor. To make this wine, three pounds of sugar, and four of fruit, are allowed to eight pounds of water. Five pounds of fruit would be better, to avoid sweetness, though in complete fermentation; the wine would then be amply strong. No brandy should be added to effervescing wines. Care should be taken in bottling, and the same attention bestowed upon genuine champagne should be bestowed on this imitation wine, which will readily repay the extra trouble. This wine arrives at perfection only in the cellar. Wine made from ripe gooseberries is good for little; but if attempted, the skins must be carefully excluded.

In such wines too little fruit in proportion is used In currant wines the fruit is always stinted, there being sufficient extractive matter and natural acid to insure, if rightly arranged, a very perfect fermentation. These wines are made too sweet, and pall upon the palate. The proportion adopted is in all cases to be increased as regards the fruit, and the skins to be excluded from the must. The recipes, so manifold, handed about for domestic wines, continually show that the true principles of making such wines are not recognized, although laid down so lucidly by Dr. M‘Culloch. British champagne is directed to be made by crushing the fruit with a mallet, and a gallon of fruit is to be put to a gallon of water; then brandy is added, and sugar of the species often to be avoided; and brandy is added again in bottling. M‘Culloch recommends boiling the fruit, in some cases, previous to fermentation. The black currant acquires, by boiling, an agreeable flavor. The success of the plan is remarkable; the more so as, in its natural state and unboiled, it is harsh. The wine made from it much resembles sweet Cape wine. The same improvement takes place in regard to the red and white currant. The boiling should not be protracted. It is always best to boil about a third of the quantity used, and to apply the rest in the natural state. The boiling must not be continued too long, because it tends to precipitate the ferment.

The dried raisin is largely used in making domestic wines; and it naturally must be analogous in some respect to certain foreign wines, because for making them the grapes are not used until they are shrivelled in the sun. Thick, sweet grape-wines are made this way. The process adopted in making raisin-wine in

England has not shown any approach, with the same materials, to the wines made of dry raisins, or such as are called *straw wines*, or some of those of Malaga. In the mode actually adopted here, whether for domestic use, or for the deceptive objects of wine-dealers to mingle with foreign wines, from two to seven pounds of raisins are employed to a gallon of water, common clayed sugar or molasses from half a pound to three or four pounds, and oftentimes from four to six pounds of tartar in the crude state are added. Yeast is not used; still the wine is never well-tasted, and to obviate that, as the bad taste may arise from the skins, cold water is used. It is necessary to apportion the sugar to the tartar. From two to four per cent. of crude tartar is a sufficient addition, giving more when the fruit is sweetest. In regard to the sugar, two pounds to the gallon of the other ingredients will produce a light wine like the white wine of Bordeaux. Three pounds will give the body of hermitage, and four that of Muscat or of Cape Madeira, before their respective doses of brandy were added to them. The sugar added must be apportioned to the quantity in the fruit. If the wine is to be a sweet wine, not less than four pounds to the gallon must be used. The water added must not be out of all proportion to the fruit—which last rarely forms a fourth of the entire fluid—and four pounds to eight of water, and three or four of sugar, supposing no regard is had to the state of the fruit in respect to its ripeness. The vegetal extractive matter in such a case is deficient, as well as the native acid, and this acts injuriously upon the fermentation, and renders it inefficient; the must, consisting of an overplus of sugar and water, cannot thus form wine. Let the principle wanted be increased, and the wine will put on the true character —the dilution of the acid, if the fruit be ripe; and if it be unripe, then the acid and extract being in excess, the operation must fail of fulfilling expectation.

Flavor may be easily imparted to all those wines which want it. Elderflowers, mignonette, clove pinks, for example—or sweet briar, wormwood, ginger, cloves, orris, and the like—will impart, either of them, or perhaps some in combination, a flavor agreeable to the taste of the maker. They are suspended in a bag from the bunghole during the first stage of fermentation. To please the eye, elderberries, or mulberries, will supply color, or what the French call *vin de fismes*—a color liquor, made near Rheims of a small bitter cherry used for the same purpose, a few drops being sufficient to color a bottle. In Holland, tournsel is used for the same purpose—the *crotum tinctorium* of Linnæus. It is naturally of a blue color, but on coming into contact with an acid it immediately takes a red hue. In France it is said that color derived from woods, as Brazil or logwood, do not long resist the acid of the wines; and, therefore, they find it better to darken the light hue of wines by mingling deep-colored wine with them. This, however, need not deter from the use of such means to suit the eye in domestic wines of English fruit. Bitterness may be obtained by the use of burnt sugar, as well as yellow tints. Cognac brandy for the English market is thus colored in France, where the people use the pale spirit.

All vinous operations require great care and sound judgment. In fining home-made wines, the same management is necessary as in treating the grape-juice with a similar object. The imitation wines made in the household must first be considered in regard to the model immediately in view. If the object be a sweet wine, of which the fermentation is incomplete from the want of sugar in the must, or if its suspension be by design as before described, the operation to be followed is clear.

If the wine be designed to sparkle or effervesce, the cause and mode of acting has been shown; and that briskness is not much in accordance with sweetness. Though generally made of the gooseberry, any other fruit in a proper state of immaturity will answer as well. The use of carbonate of potassa or soda must be avoided, because the gas is almost all disengaged in the first glass on pouring out, before the wine can be drunk, nor has it anything like the effect of carbonic acid gas in the wine. It also deteriorates the taste, and destroys the native acid, replacing it with an alkali.

The Rhenish wines have never been successfully imitated, and for the paramount reason, that their constituent parts are so accurately balanced that they would require great judgment, and much care, in the process; the fermentation must be perfect, and exact proportions be carefully kept in the ingredients. Even then their preservation would require great attention. Fining, racking, and sulphuring, must be had recourse to by hands often not adepts in their use. The dry wines of some strength, imitative of Sherry and Madeira, may be made strong enough without the addition of brandy, which, however, may be added to them by the operator, if he sees it requisite.

Dr. M'Culloch recommended that wine should be made from grapes grown in England. The grapes may not ripen in some years, and in an agricultural view it is profitless; but wine is continually made by cottagers in Sussex from the grapes grown in front of their houses, and some species ripen a full month before others. The white muscadine, the two varieties of the chasselas, the black Hamburg, and others, are of this class. But to make domestic wine from the grape in England, does not demand that the grape should reach the maturity required for its wines, as the term is generally understood. A crop of grapes is certain, if not always a ripe crop. A compound artificial must can be made from the admixture of sugar with the extractive and other matter of the fruit, which, undergoing a regular fermentation, forms a perfect wine, as applicable to the grape as the gooseberry. The experiment has been tried and found successful, and domestic wines made this way declared excellent. Three pounds, or less, of sugar to the gallon, with the hardiest grapes, produce a wine of the strength of red hermitage, not void of flavor, but the reverse. Dr. M'Culloch mentions the proportions he found needful, both of sugar, water, and other substances necessary for the purpose. He kept some of the wines twenty years, and found them as little liable to destruction as the wines of France.

The want of judgment, the haste, the non-comprehension of the chemical principles upon which wine is made from domestic fruits, the want sometimes of a clean palate on the part of the maker, and the abandonment of a nice operation to the hands of servants and old housewives, have caused great mistakes in the manipulation of these wines. Dry wines of the first quality do not require that maturity of the grape which is so necessary to those which are sweet. In the first case sugar can be added; but the customary notion of the ignorant in this, as in other cases, often prevails, and the neglect of the green grape for the green gooseberry is a striking proof of it. Nor is this all; for it has been proved by chemical examination, that the tendrils, shoots, and even the leaves of the vine themselves, possess exactly the same qualities as the crude fruit. Experiments were in consequence instituted in France, to try if they would not answer for the purpose, and they were satisfactory; but there, where the fruit was to be had in any state, the matter naturally terminated; while in England it was different. The success of the attempt was decisive, on adopting the management had recourse to in treating wine from other unripe fruit. Only young or half-green vine leaves are selected, together with the tendrils. The old leaves are not proper. The month of June is the right season to pluck them. The vines for the purpose may be planted anywhere, and suffered to run up unpruned. Close imitations of the sparkling wines of Champagne and of St. Peray have been made this way, and none were made that were not as good as the ordinary sweet wines of the Cape. If the wine is too sweet from want of the vegetable extract in a sufficient quantity, a fresh infusion will reinstate the fermentation. The wine of a defective year in goodness, may be renewed the next season. The leaves should be infused sometime before they are used, yielding their virtues more readily to hot than cold water without any material difference in the result. Half a pound of crude tartar, or more, within a pound, to two gallons of must, is useful. The expense of the sugar here is nearly the whole incurred, and a single vine will supply a family, as the leaves are successive.

A few specific directions under the scientific authority before mentioned:—The cask measure being supposed ten gallons, will illustrate the foregoing principles; those adapted to the lands of the vine being kept in view as guides, where any difficulty may occur. In a tub or vat carefully cleaned, that has a capacity for fifteen or twenty gallons, forty pounds of the gooseberry of the green Bath kind are introduced, avoiding any that are ripe. Reject the unsound, and remove the blossom and fruit-stalk, or their remains. The small berries may be separated by a sieve. The fruit is to be bruised into the vat by a pressure sufficient to break the skins, without fracturing the seeds or compressing it too much. Four gallons of water are then poured in upon the fruit, and the whole is carefully stirred and compressed with the hand, until the juice and pulp are separated from the solid matter. The materials must rest for ten or twenty-four hours, and then be strained through a coarse bag with as much force as can be easily applied. A gallon of fresh water is to be added to the mash, to remove any soluble matter remaining. From twenty-five to thirty pounds of white sugar are to be dissolved in the must or juice thus obtained, and the mass of fluid increased by more water to ten gallons and a-half. This difference in the weight of the sugar is to balance any in the quality of the fruit, the discovery of which difference must depend upon the judgment of the operator. Old haphazard receipts gave forty pounds of sugar, which of course make a sweet wine, continually failing in effervescence on that account. The must is next to be placed in a tub or vat, over which a blanket is thrown, and a board over that, and the whole kept in a temperature between 55° and 60°, to remain from twelve to twenty-four hours, according to the state of the fermentative process. It is then to be drawn off into a cask until the fluid nearly reaches the bung-hole, so that the scum which ascends to the surface may overflow, and be thrown out. As the fermentation goes on, and the bulk of the liquid diminishes in the cask, the superfluous must made for that purpose must be poured in, so as to keep the liquid always near the bung-hole. When the fermentation diminishes still more, which may be judged of by the reduction of the hissing sound, the bung is driven in, and a hole bored on one side of it, into which a wooden peg is put, and in a day or two taken out, in order that the gas within may have vent. It is then restored and reopened to let the gas again escape, until, there being no longer any danger from the expansion, it is tightened for good. The wine is to be kept over the next winter season, in a cool cellar, and on a clear sharp day about the beginning of March, if fine, it is bottled; if not fine, or to insure its fineness, if doubted, at the end of December it is decanted into a fresh clean cask, to free it from the lees, which, if the wine be too sweet, instead of drawing it off, should then be stirred up in it, increasing the temperature to renew the fermentation. When drawn off, it is fined with isinglass; and if not clear, the operation is repeated in dry, clear, cold weather as before, and bottled in March, and not later. Such a wine is brisk like champagne, and similar in quality, but stronger, differing in little but the flavor. Sometimes the wine will be still, like sillery, or sweet, without close attention to the process; at other times it will be dry. If sweet and still, it may be remanufactured the next season by renewing the fermentation, and repeating, under the addition of fresh juice or must, the former treatment. If it be dry, it remains so, and may be drawn off into a sulphured cask, and then fined and bottled. Any peculiar and not agreeable taste, during the first year, will go off by age. Such wines are best when drunk at five or six years old. In making the foregoing wine, the mode in managing grape-wine—fermenting the husks or skins as well as the juice with the sugar—may, on the other hand, be adopted in the earlier stage of the operation. The rapidity of the fermentation in this way is much increased; the wine, stronger and less sweet, will gain more flavor. Crude tartar, to the extent of six ounces to the ten gallons, is sometimes added. Sweetness with briskness, though the latter quality is hazarded, may be had by using sugar to a greater extent under forty pounds. Brisk domestic wines are not durable nor strong, and must be drank very early from want of the capacity for keeping. Effervescence without sweetness is obtained by increasing the fruit, as in the proportion of fifty pounds of fruit to thirty of sugar.

The wine made from unripe currants, under the same general process as the former, requires that the stalks be separated with care. The must of this fruit is much easier to manage than that of the gooseberry, and it is far better calculated for brisk wine, and less likely to carry a bad flavor.

Nothing but the pure must is introduced into the cask—not a particle of the mash. If, in the fermenting in the vat, the scum, crest, or head, called the *chapeau* by the French, be tainted with sourness or mustiness, it must be at once removed; and when the fermentation of the mash does not take place with the must, the latter may be at once introduced into the cask.

Mature gooseberries and currants are made to produce dry and sweet wines by the foregoing modes. In sweet wines the fruit should not be above forty pounds; if in dry, it should be carried to sixty. The sugar should be full thirty pounds, unless a strong wine is desired, when forty pounds must be employed.

Wines from elderberries are made with the same proportions of ingredients as the former kinds, and in the same manner. If boiled fruit is taken—an operation which relates almost wholly to the black currant—the fruit must only be brought to the boiling point of the water, and the burning of it at the bottom of the vessel must be guarded against. Wine from the mature grape in this country it is not worth while to manufacture, as too few grapes ripen to make it any other than an object of curiosity, and the mode of treatment of them, described in the preceding pages, contains all that is necessary upon the subject.

It is probably due to M'Culloch that it was ever known that domestic wines could be made from immature grapes, vine tendrils, the young leaves, and the thinnings of the branches in places where vines are grown under shelter, in different stages towards maturity, no matter how different in species. No part of the vine need be feared as communicating a bad flavor. If the immature grapes be those grown in the open air, they should be taken just at their first tendency to ripen. The proportions and treatment are similar to those recommended for the gooseberry, but the husks may always be fermented in the vat with the must. Except in not breaking the seeds, no care need be taken about not bruising the fruit. The fermentation will be slow; but no obnoxious yeast is to be employed. Patience is necessary, but the operation will not ultimately be less effectual. Elevation of the temperature will excite it, if languid; as will also agitation of the cask, or omitting to replenish the fluid at the bung, so that the scum may remain upon the liquor.

The wine made from the young leaves, tendrils, and even young shoots, may be taken at any period from vines cultivated for this object, from which fruit is not expected. If the claret vine—*Clairette rouge de l'Herault*—be cultivated for the purpose, the wine will be of a red color. The leaves should be young, and sixty or eighty pounds should be introduced into a vat. In the vicinity of a large town they should be first washed, to clear them of sooty particles from the impure atmosphere. Seven or eight gallons of boiling water should then be poured upon them, and left to infuse for twenty-four hours. The water being poured off, the leaves are pressed in a press of considerable power, washed with an additional gallon of water, and again pressed. Sugar, from twenty-five to thirty pounds, is then to be added to the mixed liquors, and the whole made up to ten gallons and a half, when the same process is to be pursued as in the case of gooseberry wine. The water soon cools down to the usual temperature, it being used hot in order more effectually to extract the soluble part of the plant or fruit. These proportions are for brisk wines, which, if mismanaged, will fail of due effect. In the case of sweet wines of the same substances, from thirty-five to forty pounds of sugar must be used. As soon as the first fermentation has subsided, the wine is racked into a sulphured cask and fined. If it tend to a renewal of the fermentation, it must be racked and fined again, and even a third time. When perfected, the wine may remain in the cask as long as is desired. For dry wines the proportion of fruit to the sugar is to be the largest of all. The bung must be left open, and the fermentation, if sluggish, must be increased by heat and agitation. If the wine continues too sweet, it may be bunged down until the next spring without fining, and then the fermentation must be renewed by adding fresh must. As soon as it has become sufficiently dry, it must be fined into a sulphured cask, and again fined before bottling. The dry and sweet wines of this kind should be kept five years to be in their highest perfection. The brisk wines are drank after being six months in bottle, and are good to their third year. If they lose their briskness, they become dry, something like the Moselle or Rhine, and will keep indefinitely.

Wines, if they can be so called, are also made of dried substances, as ginger. They are composed of sugar and water, fermented with yeast and flavored with ginger. These are rather drinks than wine. The last are made by fermenting substances which possess little or none of their own extractive vegetal matter. Three pounds of moist sugar, a gallon of water to two ounces of bruised ginger are boiled, skimmed, and set to ferment with a yeast toast, flavored with a lemon to each gallon, or a little balm, and then bunged up. In about two months it is fit for drinking, having been fined with isinglass.

Mead, a very ancient domestic wine of honey, is made with sixty gallons of pure soft water, and seven gallons and a half of clarified honey, of which mellitose—see Sugar, Vol. II. p. 966—is the sweet principle. In a copper of thirty gallons capacity, having mixed the honey and water, boil it down to one-fourth, then let it off, and boil the other moiety in the same manner; and when thus reduced fill up the copper with what was boiled first, and continue ebullition and filling up until the copper will contain half the liquor, all the rest having evaporated. The liquor must not be skimmed, but the scum must be well mingled with the liquor while seething, by means of a jet. When this is done it is drawn off into under-backs by a tap in the copper, and the fluid falls to the temperature of new milk. Then it is turned up and fermented in the vessel, where it forms a thick head. When it has ceased to ferment it is closed from the air, and bottled at the end of six months, having been well worked and kept in the same cellar temperature as it had before. Aromatic flavors are often added by mixing elder or rosemary, marjoram flowers, and the like; or cinnamon, cloves, or other spices, during the process.

Raisin wine was manufactured light and dry in England of a superior kind, by Mr. Aikin, secretary to the Society of Arts in 1829. Dr. M'Culloch censured the mode in which it is generally attempted to be made, and noticed the failure which is naturally to be expected from the use of molasses, coarse sugar, and the nauseous yeast of beer, which can never be rendered vinous. He would have the native acid neutralized, and with all domestic wines use crude tartar. Mr. Aikin's wine was produced from Muscatel raisins. These, it is obvious, being sweet and dry, were not very different from some of the shrivelled and dried-up grapes with which wines are made in the South of Europe, as in the example of straw wines, for which the grapes are kept on the vine till shrivelled, and then further dried upon straw, giving a thick must, scanty in proportion to the produce, in a state of the grape so over-mature. Muscatel raisins are imported in boxes of twenty pounds weight. The fruit kept in the warehouse or shop unsold for above a year, is less approved by purchasers than when new, the rich pulp becoming mixed with the saccharine concretions. The extractive matter or gluten in the raisin is more than sufficient to ferment its sugar, and only from one-tenth to a third of the weight of the raisins is added. Cane sugar should be avoided in the unrefined state; if used it should be loaf. Sugar from honey or starch would be best, as unrefined sugar of the cane taints the wine. The raisins, without the stems, are chopped fine on a board, in the mode adopted with minced meat. Three pounds of raisins and one pound of sugar, were used to an ale gallon of water. The next process is mashing or maceration. If the former mode is adopted, the chopped raisins are placed in a tub, and hot water, a quart to four pounds of fruit, poured over them—the water not heated above 120°—to extract the mucilage. The whole is then stirred with the hand, no lumps being left, and placed in a sieve over a tub a short time to drain; this operation is repeated a second time throughout. The clamminess of the mass is by this extracted. The water for a third mash is poured on at 160°. The liquor now begins to be acidulous, with little sweetness. Three-fourths of the mash being made and tasted, to discover if it be sufficiently astringent, the stems or stalks, in part or all, are used, according as more or less astringency is intended. Hot water is poured upon the must, and the whole is well pressed by the hand. The three first mashes are now thrown into the tun, and the sugar, with as much of the last mash as will bring the must to its due proportion of one ale gallon to three pounds of fruit and one of sugar. The operation so far requires four or five hours; the temperature of the must is about 70°. The liquor soon ferments according to the atmospheric temperature and its treatment, but generally within thirty-six hours. The scum is either duly removed, or suffered to remain till the wine is drawn off. If the fermentation is languid, the cover is kept on the tun and the scum stirred into the liquor; if too rapid, the cover is taken off and the scum removed as it rises. The must is thus become vinous, and is transferred to carboys, or stone-ware barrels, holding six or seven gallons. Safety tubes of glass are placed in the bungs, and on the second day an inch of quicksilver in the tube, to exclude the air. The bungs are covered with a cement consisting of wax and rosin. Carbonic gas bubbles through the quicksilver for some weeks, when it ceases. The wine should remain for the summer in the carboys, or barrels, if the latter be used. The wine thus made in April should be bottled in March, or if made in October, be bottled in September. The wine is not fined, for a light dry wine the inventor thought would be injured by being deprived of its tannin. After a year in bottle the wine had a bouquet like elderflower. As the wine is not fined it is decanted with care to keep it clear. It is of a pale yellow color, but in a short time deepens to the tint of Bucellas, having a flavor something like prussic acid at uncorking, which disappears. If, in place of mashing, maceration is applied, putting the chopped raisins and sugar into cold water, a higher colored wine is obtained, the fermentation is slower, and it is destitute of the elderflower bouquet, acquiring a taste from the husks of the raisins; but often this second mode of treatment answers well. It is sometimes twenty days under fermentation. Tartar is often added in making this kind of wine, but it often fails to be good—generally from the use of molasses, cane-sugar, and yeast.

Makers of domestic wines, it must be repeated, fail from not, before commencing their attempts, becoming perfectly acquainted with the mode of making foreign grape-wine, and the principles upon which it is done, which are applicable to all domestic wines, almost without exception. They are scarcely ever what they are capable of being made. In the evidence on the wine duties, before a Committee of the House of Commons, Mr. A. Walker and Mr. J. Frith were examined. They deal in wine, home-made, of all kinds, and some bearing foreign names. The wholesale price by the hogshead was five shillings per gallon. They make sixty-five thousand gallons, of which ten thousand are British port and sherry. It is estimated that six hundred thousand gallons of these wines are made. Port is imitated from the black cherry; champagne from French grapes; port, partly too with French grapes and raisins; and Cape or Pontac, with bottoms of Oporto and Spanish wines. Spirit is added to them all. Some champagne, home-made, is from rhubarb and gooseberry. It is averred that any light wine may be made to pass for home-made champagne, by means of sirup and carbonic gas, applied as if to aerated waters. However this may be in practice, Dr. M'Culloch so well explained the process of making these wines, that success is sure wherever the guide he has left is followed; and if the domestic manufacturer be not successful, it is not for want of the soundness of the principle, but of the practical action arising from its knowledge.

Wine Measures.—The imperial gallon wine measure which superseded the old contains ten lbs. avoirdupois of distilled water, or 277·274 cubic inches. The old wine gallon was equal to two hundred and thirty-one cubic inches, the ratio being nearly as six to five, or more correctly as one to 0·833111. The imperial wine-pint is 34·65925. The old English wine measures were:—

Tun.	Pipes.	Puncheons.	Hogsheads.	Tierces.	Barrels.	Rundlets	Gallons.	Quarts	Pints	Quarterns.	Cubic Inches
1	2	3	4	6	8	14	252	1008	2016	8064	58212·
	1	1½	2	3	4	7_2	126	504	1008	4032	29106·
		1	1⅓	2	2⅔	5_9	84	336	672	2688	19404·
			1	1½	2	3½	63	252	504	2016	14553·
				1	1⅓	2⅓	42	168	336	1344	9702·
					1	1¾	31½	126	252	1008	7276·5
						1	18	72	144	576	4158·
							1	4	8	32	231·
								1	2	8	57·75
									1	4	28·875
										1	7·219

Wine measures differ greatly in the European wine-making countries, and give much perplexity in conducting operations of any kind in regard to them. Thus a tun is two pipes; three puncheons, four hogsheads; six tierces, two hundred and fifty-two old English gallons; and one thousand and eight quarts, two thousand and sixteen pints. The following are some of the more common measures:—

	Old Gallons.	New Gallons.
Tun,	252	210
Pipe of Port,	138	115
Do. Carcavellos, Lisbon, Bucellas,	140	117
Do. Madeira,	110	92
Do. Sicilian, Marsala,	112	93
Do. Vidonia, Teneriffe,	120	100
Butt Mountain, } Do. Malaga, }	126	105
Do. Sherry,	120	100
Hogshead, Claret,	57	46
Do. Tent,	63	52
Ohm Rhenish,	36	30
Do. Aix-la-Chapelle,	—	35
Do. Cologne,	—	41
Do. Heidelberg,	—	29
Do. Cassel,	—	43
Do. Frankfort,	—	39

The French measures are the litre and hectolitre. The first contains 61·0280264 cubic inches; the second, 3·531714693 feet English; or the litre is equal to 2·113 pints old English wine measure, and the hectolitre to 26·4 old English gallons, or to 22·01 gallons imperial, and the litre to 4·5432. Therefore, 100 imperial gallons are 454·3200 litres. A pipe of port contains 522·3680 litres; a butt of sherry, 490·6656; a hogshead of claret, 208·9872, and an ohm of Rhenish 136·2960. In France, let the name of the cask or measure be what it may, the stranger asking the number of litres, is at once answered—the litre being the legal standard.

FRENCH WINE MEASURES WITH OLD ENGLISH.

Litres		Cubic inches.	Imperial pints.	Old wine pints.	Oz. of water, troy.
1	=	61·028	1·7608	2·11353	31·104
2	=	122·056	3·5216	4·22706	64·208
3	=	183·084	5·2822	6·34059	96·312
4	=	244·112	7·0430	8 45412	128·416
5	=	305·140	8·8038	10·56765	160·520
6	=	366·168	10·5646	12·68118	192·624
7	=	427·196	12·3253	14·79471	224.728
8	=	488·224	14·0861	16·90824	256·832
9	=	549·252	15·8469	19·02177	288·936

In some countries a troublesome variety prevails in measures of the same name. In Sweden, the ohm is 139·019 litres, or 30·543 gallons imperial; at Strasburg it is only 46·093 litres, or 10·146 gallons.

The measures for wine in Spain are commonly arrobas, of which sixteen make a mayo; twenty-seven mayos, a pipe; thirty pipes, a bottle—the last equal to one hundred and twenty-seven and a half old English gallons, or one hundred and six imperial. But the measures of the same name differ in different provinces. The arroba of Valencia contains 11·786 litres; of Malaga, 15·850; of Spain and the Canaries generally, 16·073. The cantaro of Alicante is 11·554 litres, or about three gallons, and the tonnelada is one hundred cantaros; that of Arragon, 10·313; of Oviedo, 19·236. The carga of Barcelona is 123·756; the gerra of Minorca, 12·063; the mayo of Gallicia, 161·991; the quartin of Majorca, 27·131 litres, or 7·168 old gallons.

In Portugal, the almude is 25·480 litres; of Lisbon, 16·541; of Oporto, twenty-one make a pipe; at Lisbon, thirty-one, or one hundred and forty old English gallons. At Figueras the almude is 4·75 English imperial gallons; at Viana, 5·5. All these are in use in Portugal; besides which, they have potes, canadas, quartillos, basils, and tonneladas; this last two hundred and thirty-one imperial gallons.

In Germany the ohm varies, at Hanover and Hamburg it is thirty-two imperial gallons; on the Rhine only twenty; at Ratisbon the bergeimer—about nineteen imperial gallons, and the same at Munich—seven and a half only; at Vienna it is ten and a half imperial gallons. The ohm at Basil, in Sweden, Dantzic, and Strasburg is a different measure from the German ohm. The ohm at the Cape of Good Hope is thirty one and two-thirds; the eimer of Leipzig, twenty and a half old English gallons, and at Dresden eighteen only; at Antwerp the aum or ohm is forty-two old English gallons.

The Russian wine-measure is the vedro of 2·705 imperial gallons; three vedros make an anker; six ankers, an oxhaft; two oxhafts, a pipe, or 75·320 imperial gallons.

The Hungarian measures are, the antheil of 11·125 imperial gallons; the great and little eimer—the first equal to 16·140 imperial gallons, and the second to 12·515.

The other European wine measures are of little moment comparatively. In Italy they are numerous. The oke in Greece is two pounds, three ounces, five drachms, avoirdupois; and the alma of Constantinople, 1·150 imperial gallons.

Mr. CYRUS REDDING kindly tendered some valuable matter, which the Editor has incorporated in the preceding details.

ZINC.—*Zinc*, French; *Zink*, German.—It is only from the middle of the sixteenth century that zinc has been known as a metal. Its ores were known from a very early date, and were spoken of under various names; but the first account which is recorded of the term *zinc* being used in reference to the educt from the calamine or cadmia of the period, is that of Albertus Magnus; and the first who characterized it as a distinct metal was Paracelsus, about the year 1530. For a long time afterwards, however, the knowledge of this substance was almost entirely confined to alchemists, who prized it highly on account of the property which it was thought to possess of transmuting copper into the more precious metals. It was owing to this imaginary property that the metal was long termed *counterfey* or *counterfeht* by the Germans. The present name seems to be derived from the word *zinken* or *zacken*, the German for nails or spikes, because, in preparing brass, a portion of the ore, on being submitted to a preparatory roasting, often assumed such forms. The synonym Spelter, which is now so much used in commercial language, is derived from the terms *spiauter*, *spialter*, *et cetera*—terms which were introduced along with the first portions of this metal imported from India.

That the ores of zinc were known to the ancient Greeks and Romans, is attested by the accounts which Dioscorides, Strabo, and Pliny give of one of them, or perhaps of several of them under one generic name; and likewise by the fact that in the time of these writers or at a later period, articles are known to have been produced in a kind of brass or bronze, the analyses of which clearly indicate the presence of zinc in greater or less proportion. The following analyses of different varieties of brass, dating from about the beginning of the Christian era, are given by Phillips as demonstrating this fact indisputably:—

		Copper.	Tin.	Iron.	Zinc.	Lead.
Large brass of the Cassia family,	B.C. 20	82·26	—	0·35	17·31	—
Large brass of Nero family,...	A.D. 60	81·07	1·05	—	17·81	—
Titus,....................	“ 79	83·04	—	0·50	15·84	—
Hadrian,....................	“ 120	85·37	1·14	0·74	10·85	1·73
Faustina, jun.,..............	“ 165	79·14	4·97	0·23	6·27	9·18

Of many other bronze articles analyzed by Phillips, none of them, known to have been produced anterior to the year 20 before Christ, were found to contain zinc as a constituent, tin being the material employed instead of that metal. The earth which was used in those early days for the purpose of forming an alloy with copper was termed *cadmia;* but it is evident that by this substance was not meant an oxide or silicious oxide of zinc, as at the present day, but any mineral, whether oxide or carbonate, that contained a large proportion of that metal, notwithstanding there being other metallic compounds associated with it. The alloy so prepared was known as *aurichalcum*, which was then recognized as a purer copper than the ordinary metal, and hence was more esteemed. The dross or oxidized portion sublimed from or remaining in the furnace after the alloy was drawn off, was likewise known by the general term Cadmia, but was distinguished by some particular designation, according to its color, form, or consistency. In later times this compound was distinguished at Rammelsberg as furnace calamine—*ofenbruch*—when it was discovered that it could be employed instead of native calamine in the manufacture of brass. Another substance called Tutia, which seems to have been analogous to cadmia, or at least to have been a compound also rich in oxide of zinc, is spoken of in writings of the eleventh and subsequent centuries as having been employed for the manufacture of brass. Zozimus, who is supposed to have written about the fifth century, states, that to make brass, cyprus copper must be melted and pounded *tutia* strewn upon it. According to Albertus Magnus, the celebrated alchemist Hermes taught the method of making copper of a gold color by introducing pounded tutia into the melted metal; and Albertus leaves no doubt of the nature of this tutia, for he states that it is not a native mineral, but an admixture produced in the furnace when copper ore is melted—thus showing that evidently it was a sublimed oxide of zinc mixed with other ingredients, and analogous to the furnace calamine or *ofenbruch* of a later period. The discovery that this sublimate could be substituted for native calamine in the production of brass, is said to have originated with Erasmus Ebenezer, a German, towards the middle or first quarter of the sixteenth century. The discovery was greatly esteemed, as up to that period the refuse matter from the furnaces of Rammelsberg were cast aside as useless. Doubtless the period intervening from the time of Albertus Magnus to that of Paracelsus gradually developed facts resulting in a more comprehensive knowledge of cadmia, tutia, and the other substances containing oxide of zinc, and leading as a natural consequence to the isolation of the metal. Indeed, the former of these writers distinguished the principle in the earth which was used to convert copper into brass as *marcasita aurea*, a term which might be qualified as meaning the metal of this earth, though properly it was understood at the period as a mercurial ore, probably a sulphide of mercury. This marcasita, of which Magnus speaks as superior to the other ores of zinc, was found at Goslar; but that of which Paracelsus wrote was stated to be produced at Carinthia. By Agricola, however, who wrote about the year 1550, reference is made to the Goslar product alone, which he designates as *liquor candidus* or *counterfey;* and Fabricius, who died in 1571, conjectures that *stibium* is what the miners call *cincum*, a compound that could be melted but not hammered.

From these different statements it will be seen that the knowledge of zinc, even for a long time after its recognition as a distinct metal, was exceedingly meagre; and in point of fact very few of the chemists of that period could obtain even samples of it, owing, as it is alleged, to the great hopes entertained of it as an alchemical agent, and the consequent prohibition by Duke Julius to sell it or make it generally known. However this may be, the first certain account of its production at Goslar was given in 1617 by Lœhneyss, whose note in reference to it runs thus:—When the people at the melting-house are employed in melting, there is formed under the furnace, in the crevices of the walls, under the stones where it is not well plastered, a metal which is called zinc or *counterfeht*, and when the walls are scraped the metal falls down into a trough to receive it. This metal has a great resemblance to tin, but it is harder and less malleable, and rings like a small bell. It is not much valued, and the servants and workmen collect it only when they are promised drink-money. They, however, scrape off more of it at one time than at another; for sometimes they collect two pounds, but at others not above two ounces. This metal by itself is of no use, as, like bismuth, it is not malleable; but when mixed with tin, it renders the latter harder and more beautiful, like English tin. This zinc or bismuth is in great request among the alchemists.

Beckmann Kenkell is accounted to have been the first who procured it directly from calamine in 1741. After him Lawson is stated to have succeeded in extracting it from the ore, though no account of his researches exist. Von Swab, a Swede, obtained it by distillation from calamine in 1742; and almost contemporary with him Marggraf likewise discovered a process for the same purpose in 1746. It is stated by Watson in his chemical essays, that in 1743 a manufactory for the production of this metal was established at Bristol, by Champion, and was carried on by his successor, Emerson, who established another in the neighborhood. It appears, however, that the wants of Europeans, as regards this metal, were supplied from China and India, through the Dutch, and probably the Portuguese, the imported articles hearing the title *tutenague*, or Indian tin. Raynal records that the Dutch East India Company purchased annually at Palimbang a million and a half pounds of this metal; and the Danish Company at Copenhagen, in 1781, as much as one hundred and fifty-three thousand nine hundred and fifty-three pounds. It appears, however, that between the above date and 1820 the production of zinc must have greatly increased, as it is recorded that at the latter date spelter or zinc was imported into England from Silesia, to be again exported to India to supply the place of the *tutenague*, formerly imported from China. The Silesian zinc was analogous in composition to the Chinese product, as will be seen by the subjoined figures :—

	Zinc.	Lead.	Iron.	Sulphur.	Sand.
Silesian zinc, ...	98·32	1·40	—	0·18	0·10
Chinese tutenague,	97·63	0·33	1·90	0·14	—

The quantity exported from England to India almost balanced the total amount of her imports, until about 1830, when the quantity retained for home consumption began to be increased annually, so that in 1851 the amount thus utilized reached eleven thousand two hundred and sixty-two tons, while the quantity imported in the same year amounted to eighteen thousand six hundred and twenty-six tons, whereas the exports to India remained nearly the same. At present Silesia is the great seat of the manufacture of zinc, containing the largest works of the kind in the world, and producing as much as fifty-three per cent. of the total yield of all countries. Belgium, including more especially the works of the Vieille Montagne Company of Liege, ranks next, and produces about thirty-three per cent.; Poland and Cracow furnishes ten and a quarter per cent., and England the remainder.

The application of zinc within the last twelve years has been very much extended, not only for use in brass foundries, but in several other departments, such as in galvanizing iron for light roofing and for fencing, and in fact for all the lighter kinds of iron which have to be exposed to the air; for the base of electro-plated articles, for paint, and various other applications.

Occurrence of Zinc.—This metal is never found in the native or virgin state, but always combined with oxygen, sulphur, and salt radicals. Ores of zinc are met with in almost every country, though not to such an extent in many of them as to render them particularly important in a metallurgical point of view. The most remarkable deposits of these ores hitherto discovered are those in New Jersey in the United States, where almost every variety of the natural combinations of zinc are met with. They exist in considerable quantities in Siberia and on the continent of Europe, more especially in Silesia, Hungary, Carinthia, Saxony, Belgium, Sweden, and France; also in England and Scotland, and some parts of Ireland. The most famous localities where the deposits occur will be mentioned presently in specifying the particular ores of zinc.

Ores of Zinc.—The most important ores of zinc, not only as containing more of the metallic element, but also as affording greater facilities for its extraction, are the oxide, carbonate, sulphide, and silicates.

Oxide of Zinc—Spartalite—*red oxide of zinc, zinc oxide ferrifère; zinc erze; zinkit.*—Generally this ore is met with in the amorphous state, but it is occasionally found crystallized in forms of the rhombohedral system, the crystals appearing colorless or yellowish-red, according to the purity of the compound; their lustre is adamantine, appearing translucent on the edges, having a cleavage parallel to the base and one of the sides, a conchoidal fracture, and a specific gravity equal to 5·43 to 5·52. Crystallized oxide of zinc is infusible before the blowpipe, though it phosphoresces strongly; with horax and phosphorous salt the presence of manganese is indicated in it, while that of zinc is shown by the green color produced in the assay, when it is moistened with nitrate of cobalt solution, and subsequently heated to strong redness. The powdered crystals, as well as the amorphous substance, dissolves readily without effervescence in nitric acid. Its composition is—

	Whitney.		Hayes.	Berthier.
Oxide of zinc, ...	94·45	96·19	93·48	88·0
Oxide of manganese,	trace	3·70	5·50	12·0
Franklinite, ...	4·49	—	—	
Oxide of iron, ...	—	0·10	0·80	
Loss by ignition, &c.	1·06	0·01	0·22	
	100·00	100·00	100·00	100·0

CARBONATE OF ZINC—*calamine; zinc carbonaté, Galmei-Smithsonite; zinc spar.*—This is by far the most important ore of zinc, and that from which the metal is chiefly extracted; it is more diffused than any other, and offers, like the oxide, peculiar facilities for smelting. Calamine is usually found in a crystallized state, in concretioned and compact masses, and in pseudomorphic forms. The crystallized variety when pure has a vitreous, inclining to a pearly lustre; is colorless, white, grey, green, or brown, according to its freedom from extraneous matters. Its crystalline form is that of the rhombohedron, with a cleavage parallel to its faces. Its fracture is uneven or imperfectly conchoidal; its streak white, and its specific gravity 4·34 to 4·45. The ore is infusible before the blowpipe, but affords a white sublimate of oxide of zinc when it is heated on the charcoal, and which is yellowish while hot, and becomes white on cooling. By moistening the assay with a solution of nitrate of cobalt, and then heating, the green color peculiar to zinc under such treatment makes its appearance. It is readily soluble in acids with the evolution of carbonic acid, and in an excess of caustic potassa. The following analyses of a few samples of the mineral indicate its composition:—

	Smithson.		Karsten.			Berthier.
	1	2	3	4	5	6
Oxide of zinc,	64·8	65·2	57·76	64·53	64·36	60·7
Carbonic acid,	35·2	34·8	35·62	35·47	35·14	35·0
Protoxide of manganese,	—	—	6·62	—	—	—
Oxide of lead,	—	—	—	—	0·50	—
Oxide of iron,	—	—	—	—	—	4·3
	100·0	100·0	100·00	100·00	100·00	100·0

Samples 1 and 2 in the preceding table represent calamine from Somersetshire and Derbyshire; 3 is from Nertschinsk, 4 from Altenberg, 5 from Brilon, and 6 from Taina in Siberia.

Annexed are a few analyses of other samples of calamine more manganiferous than the foregoing. Number 1 specimen represents the calamine in yellowish white crystals from Altenberg; No. 2, light green crystals from Nirm; No. 3, dark green crystals; and No. 4, calamine from Nertschinsk:—

	Monheim.			Kobell
	1	2	3	4
Carbonate of oxide of zinc,	84·92	85·78	74·42	96·00
Carbonate of protoxide of iron,	1·58	2·24	3·20	2·03
Carbonate of protoxide of manganese,	6·80	7·62	14·98	—
Carbonate of oxide of lead,	—	—	—	1·12
Carbonate of lime,	1·58	0·98	1·68	—
Carbonate of magnesia,	2·84	4·44	3·88	—
Silicate of oxide of zinc,	1·85	—	—	—
Silica,	—	0·09	0·20	—
Volatile matter,	—	—	0·56	—
Loss,	0·43	—	1·08	0·85
	100·00	101·15	100·00	100·00

Very frequently the silicated oxide of zinc and the carbonate are confounded under the title calamine. Two principal classes of calamine are recognized, namely, ordinary white calamine, which may be a carbonate or a silicate of the oxide, containing but a very small proportion of ferruginous matters, and the *red*, which differs from the foregoing, but only by its containing more hydrated sesquioxide of iron or its salts.

The following are analyses of red calamine by JOHN:—

	From Rudipikar.	From Beuthen.
Oxide of zinc,	39·00	35·00
Carbonic acid and water,	15·00	24·37 10·63
Oxides of iron, manganese, lime, and silica,	46·00	3·000
	100·00	100·00

Calamine, as well as *blende*, is found in two geological formations—the one is the carboniferous or mountain limestone, in which it occurs in veins accompanying galena; and the other the magnesian limestone formation of English geologists, the Alpine limestone of the French, and the *Zechstein* of the Germans, in which it is disseminated in small veins forming a network in the mass, not more than a few inches in thickness, except where several intersect, when it sometimes increases to as many feet. Explorations for lead and zinc are carried on in England, wherever the mountain or metalliferous limestone exists; but the principal seats of operation are in the neighborhood of Alston Moor in Cumberland, of Castleton and Matlock in Derbyshire, and in Flintshire in Wales. In the magnesian limestone the explorations for calamine are prosecuted chiefly on the flanks of the Mendip hills, near Bristol; and the mineral is excavated by means of numerous small shafts and levels. Calamine usually occurs in beds and veins, associated with Smithsonite galena, blende, and other minerals, in the crystalline slates, transition rocks, the coal formations, the muschel kalk, and oolite formations. It is found at Altenberg and Nirm, near Aix-la-Chapelle; at Iserlohn and Brilon in Westphalia; near Tarnowitz in Silesia; at Raibel and Bleiberg in Carinthia; in the Banat; at Miedziana Gora in Poland; Dognazka, Rezbanya, and Saska, in Hungary; at Kucsiana in Servia; Tschairski in the Altai; Nertschinsk and Nischn Tagilsk in Siberia; Chessy in France; in Belgium; in several places in the United States, especially in Jefferson County, and many other localities.

SILICATE OF OXIDE OF ZINC—*Smithsonite*, Phillips; *zinc oxidé silicifère*, Hauy; *zink-glas*, Hausmann; *galmei*, Haidinger.—Two varieties of this mineral exist;

the one anhydrous and the other hydrated. Anhydrous oxide of zinc is found crystallized in regular hexahedral prisms of a green or grey color; translucent, sometimes transparent, with a vitreous lustre on the surfaces of the fracture, which is somewhat conchoidal and uneven. Its streak is white. Before the blowpipe it is infusible, and is only reduced when mixed with charcoal, and submitted to a very high temperature; heated with soda on charcoal, it affords a sublimate of oxide of zinc; with a solution of nitrate of cobalt it affords the characteristic green color of zinc; it is decomposed by mineral acids, yielding a jelly of silicic acid. It is composed of—

Oxide of zinc,	71·32
Oxide of lead,	2·66
Oxide of iron,	0·67
Silicic acid,	25·35
	100·00

HYDRATED SILICATE OF ZINC—*Electric calamine.*—Silicates of zinc, especially this variety, were long confounded with calamine or carbonate of zinc, notwithstanding the great difference which exists between the two minerals. Electric calamine occurs in stalactic, mammillated, botroidal, and massive forms, as well as in crystals of the right rhombic system. Its usual color is white, but in this respect it varies to shades of yellow, brown, green; its lustre is vitreous, and its streak white; it is phosphorescent when rubbed, and becomes electric by heat; its streak is white; it has an uneven fracture, and a specific gravity of 3·3 to 3·6. When heated on the mattrass it yields water and turns white. It swells on charcoal before the blowpipe, and shines with a green light, but does not fuse, excepting a little on the edges; in other respects it comports itself like the anhydrous compound. The pure silicate is composed of—

Oxide of zinc,	67·07
Silicic acid,	25·48
Water,	7·45
	100·00

corresponding to the formula $ZnO, 2\ SiO_2\ HO$. In most cases, however, this mineral is associated with various extraneous matters, as shown in the annexed analyses—

	Berzelius.	Berthier.		Smithson.	Thomson.
	1	2	3	4	5
Oxide of zinc,	66·84	66·0	64·5	68·3	66·8
Silica,	24·89	25·0	25·5	25·0	23·2
Oxides of lead and tin,	0·28	—	—	—	—
Water,	74·45	9·0	10·0	4·4	10·8
Carbonic acid,	0·54	—	—	—	—
Loss,	—	—	—	3·3	—
	100·00	100·0	100·0	101·0	100·8

Numbers 1 and 2 in the foregoing table were from Limburg, 3 from Breigau, 4 from Rezbanya, and 5 from Leadhills.

This mineral is generally associated with calamine in veins containing iron and lead ores and blende; it is found in most of the localities already mentioned as containing calamine. Considerable quantities of it are mined at Bleyberg and Raibel in Carinthia; in Brisgau, Hungary; and at Tarnowitz in Silesia; it is also found in Poland, Gallicia, Baden, in the Tyrol, and in Banat; at Alcarez in Spain; at Altenberg, near Aix-la-Chapelle; at Moresnet, near Liege; near Goslar in the Hartz; at Matlock, Derbyshire; in the Mendip Hills and Flintshire in England; at the Wanlock-head; and the Leadhills in Scotland, and several other localities.

SULPHIDE OF ZINC—*Blende; zinc sulfuré; zinkblende.*—Blende occurs in a variety of conditions—massive and crystallized in octa- and dodecahedrons and other allied forms, derived from the cubic system, its color varying between black, brown, red, yellow, and green. The crystallized variety is translucent, transparent, and opaque; it has an adamantine lustre, a conchoidal fracture, and a cleavage parallel to several of its faces; it gives a white, shading off to a reddish-brown, streak, according to its purity; it is brittle, and has a specific gravity of 4·0 to 4·1. By friction some varieties are rendered electric. Heated alone it decrepitates violently; it is infusible, excepting slightly on the edges in the blowpipe flame; but it gives, under a strong oxidizing flame, a sublimated areola of oxide of zinc round the assay; with carbonate of soda on charcoal it is reduced. When treated with nitric acid the base is dissolved, and the sulphur left in proportion to the strength of the acid employed. When pure, sulphide of zinc consists of equivalent proportions of its constituents, corresponding to the formula ZnS, and is composed centesimally of—

Zinc,	67·03
Sulphur,	32·97
	100·00

Generally, it contains several impurities, such as sulphides of iron, of lead, of cadmium, and of antimony; the first of these is more frequently met with in the dark, and the second in the reddish striated kind. The following are analyses of a few samples of blende from different localities; namely, those marked 1, 2, and 3, from Przibram; 4, a transparent variety from New Jersey; 5, from Bagnères de Luchon; 6, from Chérones, in the department of Charente; 7, from Raibel in Carinthia; 8, from Eaton; 9, from Shelburne in New Hampshire; 10, from England; and 11, from Christiania:—

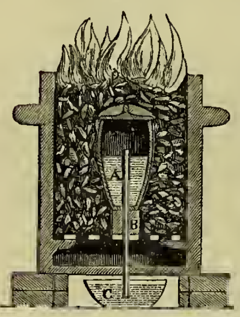
	Lowe.		Arfredson.	Henry.	Berthier.	Lecanu.	Kersten.	Jackson.		Berthier.	Scheerer.
	1	2	3	4	5	6	7	8	9	10	11
Zinc,	61·40	62·62	66·34	66·46	63·0	55·0	64·22	63·62	52·0	61·5	53·17
Iron,	1·29	2·20	—	—	3·4	8·6	1·32	3·10	10·0	4·0	11·79
Cadmium,	1·50	1·78	—	trace	—	—	trace	0·60	3·2	—	—
Antimony, lead, and oxygen,	—	—	—	—	—	—	0·72	—	—	—	—
Manganese,	—	—	—	—	—	—	—	—	1·3	—	0·74
Sulphur,	33·15	32·72	33·66	32·22	33·6	36·2	32·10	33·22	32·6	33·0	35·73
Water,	—	—	—	—	—	—	0·80	(earthy matters 1·5)			—
Loss,	2·66	0·68	—	1·32	—	0·2	0·84	—	0·9	—	—
	100·00	100·00	100·00	100·00	100·0	100·0	100·00	100·54	100·0	100·0	101·43

Blende is found, as before stated, in the metalliferous mountain and magnesian limestone, especially in England, in veins and beds associated with lead, iron, and copper ores. In Cornwall its presence is observed in the older transition rocks, and chiefly accompanying copper pyrites. The variety so found, from the large quantity of sulphide of iron, is mostly of a black color—hence the miners term this mineral *black jack*. The ore is found in more or less abundance in Hungary, Transylvania, Bohemia, Carinthia, and the Hartz; large quantities of it are obtained in Cumberland, Derbyshire, and Cornwall, in England; Flintshire, in Wales; in Perthshire, the Leadhills, and the coal fields round Edinburgh and Lanarkshire, in Scotland.

Sulphate of Zinc.—*Goslarite*, *zinkvitriol*, *white vitriol*, *aluminate of zinc*, *gahnite spinelle*, *zincifère*, and a few other minerals of zinc exist; but their importance in relation to their abundance, or for their application in the metallurgy of zinc, is not so great as to require a description here.

Preparation of Zinc.—To obtain perfectly pure zinc is a task of some difficulty, so much so that the commercial article is never met with in a pure state, but rather with variable quantities of arsenic, cadmium, tin, lead, manganese, iron, cobalt, and nickel. In order to obtain perfectly pure metal, the purest commercial zinc should be dissolved in dilute sulphuric acid, filtered from any residue, and the foreign metals thrown down by immersing plates of zinc in the liquid till no further deposit takes place. After separating the precipitated metals, which may be tin, lead, copper, cadmium, antimony, and a trace of arsenic, the solution is treated with carbonate of soda, and the carbonate of zinc, which falls after filtration and thorough washing, is dried, heated to redness to expel carbonic acid, mixed with charcoal or lampblack, and introduced into a crucible as represented in Fig. 623, placed in a furnace, and the metal reduced and recovered by the method known as distillation *per descensum*. In this figure, the crucible wherein the mixture of carbonate and charcoal is placed, is shown by A; it rests upon a disc of clay, B, which, together with the bottom of the crucible, is perforated for the purpose of passing a clay tube through both, one end of which opens at the top of the crucible near the cover, and the other dips into a cup of water, C, placed beneath the grate and ash-pit. The crucible being fixed, with its charge and its cover closely luted with clay, is placed in the furnace and heated to whiteness, when the reduced particles of the metal pass off in vapor, which finds an outlet in the lower opening of the tube, and condenses in the cup of water in grains. The zinc obtained in this way will be very pure, but to obtain it in absolute purity, it is necessary to have recourse to electrolysis from a solution of zinc which has undergone the above-mentioned purifying operation, and from which the iron, manganese, and other bodies which may be deposited on the electrode, are separated by treatment with an excess of caustic potassa, subsequent precipitation of the zinc as carbonate, washing, and re-solution. The distillation of zinc being always conducted at a white heat, a repetition of the distillation, however often repeated, is not sufficient to separate many impurities of a metallic nature, which greatly injure its properties, and prevent its applications in many operations of a chemical and manufacturing nature. The substances with which it is most liable to be contaminated when prepared in this way, are lead, tin, antimony, cadmium, and arsenic, as these metals evaporate with the zinc and alloy themselves with it. A simple process adopted to free zinc from several of the preceding metals consists in incorporating some sulphur alone or mixed with grease in the melted metal, and stirring the whole rapidly with a wooden slip. The foreign metals are by this operation converted into sulphides, but traces of them are still retained in the melted zinc. Another method is to granulate the zinc by melting it in a crucible, and pouring it while fluid into a tub of water, then mixing the powder with a quarter of its weight of nitre, and introducing the mixture into a crucible, taking care that a portion of the salt rests beneath and upon the metal. The crucible is then heated in a furnace till vivid combustion ensues, after which it is taken from the fire, the slag removed from the surface, and the melted metal poured into water. Arsenic and iron are thus removed.

Fig. 623.



Properties of Zinc.—When pure, this metal has a bluish white color, somewhat similar to lead or aluminium, and a strong metallic lustre. It crystallizes in long regular hexagonal prisms, according to Naggerath, but others give the crystalline form as cubic prisms. Nickles asserts that zinc distilled in an atmosphere of hydrogen forms well-defined pentagonal dodecahedrons on cooling. When freshly fractured, its crystalline texture is lamellar, the plates sometimes appearing of considerable size. At ordinary temperatures it is brittle, of a moderate hardness, and difficult to file, but when heated between 212° and 300° it acquires a considerable degree of malleability, so that it can be drawn into wire or rolled into thin bands and sheets. Mr. Ford of Coalbrook Dale, who, according to Gray, was the first person in England who employed the metal in casting fire-engine cylinders, states that, by the mere warmth of the hand, the strips of metal which were as brittle as glass at the ordinary temperature, could be wound round the finger like slips of paper. If the heat be raised to 400° or 410° its ductility is destroyed, and it becomes so brittle as to be reduced to powder in a mortar by ordinary grinding processes. Zinc emits a peculiar odor when rubbed. Its density, according to the mean of several experiments of Brisson, Karsten, Playfair, and Joule, is 6·89; the melted metal after cooling gave Joule only 6·54. It fuses at 705° according to Guyton Morveau, but Daniell gives the fusing point 774°; at white heat it boils, emitting vapors which burn in the air or in oxygen gas with a very brilliant white light, producing oxide of zinc, which condenses in filamentous flocks on a cold surface held over the flame, or on the walls of the crucible in which the combustion is effected; this is the *philosophical wool*, the *flowers of zinc*, or *pompholyx* of the old chemists. At a red heat zinc decomposes water, setting free the hydrogen of the vapor; the same effect is produced at ordinary temperatures under the influence of weak acids, and with considerably greater energy than by heat alone. In the latter behavior a remarkable difference is manifested when pure and commercial zinc are submitted to the action of the same acid, the former dissolving so slowly that it requires the action to be continued for a period of eight days to produce the same effect as that which is effected upon the latter in a space of one hour. This behavior was made the subject of a careful investigation by DE LA RIVE, who found that the action of the acid is increased by the presence of certain proportions of many metals. By alloying nine parts of pure zinc with one part of the several metals mentioned below, and employing dilute sulphuric acid, he found that the effect of the acid, measured by the volume of hydrogen disengaged in equal times, stood in the relation of the annexed numbers :—

	Gas disengaged.
Commercial zinc and alloys of zinc and iron,..	100
Alloy of zinc and copper,....................	43
Alloy of zinc and lead,......................	15
Alloy of zinc and tin, ...	12
Distilled zinc, ...	5

One twentieth of the quantity of iron alloyed with zinc is sufficient to produce an effect equal to that of commercial zinc, and even a spiral of platinum round a bar of zinc was found to increase the action of the acid considerably. On the other hand, he observed that the acid which effected the most rapid solution of the metal, was a mixture of thirty-three parts of sulphuric acid and one hundred of water. The consideration that the zinc, on being alloyed with any metal, constitutes a kind of battery within itself, and the knowledge that the above acid is the one which possesses the greatest power of conducting electricity, led M. DE LA RIVE to the conclusion that the greater or less energy with which a plate or bar of zinc decomposes water, is dependent upon the galvanic effect of the metals associated with the zinc and of the acid body employed.

Zinc abstracts oxygen from a great number of acids containing this element. Boiling solutions of potassa and soda likewise oxidize it with disengagement of hydrogen, the oxide of zinc formed dissolving in the alkali, and forming probably the radical of an alkaline salt. Exposure to dry air, however long continued, is insufficient to tarnish bright metallic zinc; but when moisture is present it readily undergoes oxidation, a whitish coating forming upon it; this, however, retards to a great degree its further corrosion by atmospheric influences, so that it resists exposure very well; and hence, its very extended use in roofing and other applications where iron would soon become oxidized and worn away. Zinc forms an extended class of salts with acids, many of which are of some importance in many departments of art and manufactures as well as in medicine, and the metal itself has of late years been applied to a great many important uses. Zinc has the atomic or combining number 32; and its symbol, or chemical formula, is Zn.

METALLURGY OF ZINC.—The principal places for the production and manufacture of zinc are, in England, Swansea, Carlisle, Bristol, Birmingham, and the neighborhood of Sheffield; Flintshire in Wales; Upper Silesia in Germany; and Vieille Montagne in Belgium. The latter establishment has considerably increased during the last twelve years, but it has not attained the magnitude of the Silesian works, which are the largest of the kind in the world.

ENGLISH PROCESS.—The ores which are principally employed at Bristol and Birmingham, are those from the Mendip Hills and from Flintshire, while the Sheffield furnaces derive their stock from Alston Moor in Cumberland, and from Derbyshire. A large quantity of blende is likewise obtained from Cornwall, which is submitted to a preparatory roasting. The ore is sorted, and any blende which may be mixed with it is separated from the calamine; the latter is sometimes ground under head rollers, and roasted in a reverberatory furnace, to expel all its moisture and carbonic acid. This preparatory roasting is not universally practised, however, as some smelters merely break it up into fragments about the size of a pigeon's egg, and in this state mix it with its bulk of coal or slack, and submit it to the reduction process. Blende is always roasted before reducing it to metal, for which purpose it is sorted and broken up into small pieces of about half a cubic inch, and introduced into a reverberatory furnace, where it is roasted during ten to twelve hours without intermission. The furnace is ten feet long, eight feet wide, a half foot between the bed and the roof in the middle, and one foot and a half at the bridge. A continual rabbling is given to the ore, which is spread on the bed to the depth of four or five inches. During the period of the roasting, the ore suffers a loss of twenty per cent. from the sulphur expelled. Four tons of coal are said to be consumed during each operation. The charge for reduction is then compounded of one part of calcined blende, one part of roasted calamine, and two parts of charcoal. In the English system, the furnaces shown in the annexed figures are employed; their peculiar feature is their being adapted to the practice of the system of distillation *per descensum*. They consist, as shown in Fig. 624, of an inner cupola, A A, enclosing a double row of crucibles, G G, the whole enclosed by a hovel or conical brickwork chimney, D, similar to that of a glass furnace or pottery kiln. A number of openings, B B, are constructed in the cupola corresponding to the number of pots in the furnace, and which serves to charge and secure the pots in their places when necessary. For the convenience of the workmen the outer cone has doors, C C, before each pot. A fire, F, runs across the centre of the hearth and heats the row of four pots on either side, the smoke and gases passing off by the apertures, B B, and outwards at the mouth of the cone, D. The ash from the grate falls into the pit, E, at either side of which, and beneath the pots, is a gallery, H, where a number of dishes or other vessels are placed for collecting the zinc, conducted to them by iron pipes, having one end inserted into the aperture in the bottom of the pot, while the other

Fig. 624.

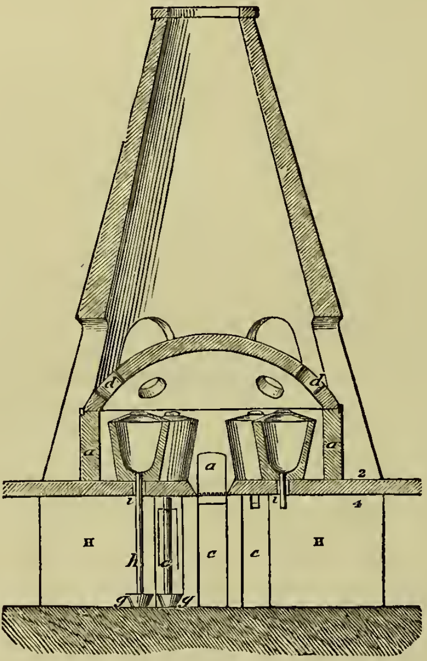
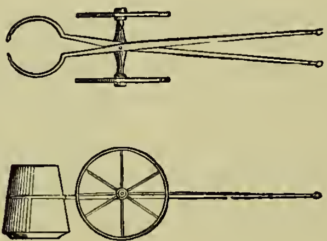


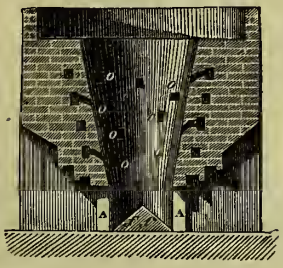
Fig. 625.



dips into the dish already mentioned. To charge the furnace, the crucibles, which are previously heated to redness in a reverberatory furnace, are carried by a pair of large iron pincers, slung in chains, and supported on a kind of over-head railway—Figs. 624, 625—much in the same way as glass-pots are inserted and withdrawn from the furnace. They are then introduced by means of an aperture in the side of the dome, and placed in their position beneath the apertures in the top, so as to rest on each side of the wall of the furrow opening into the chamber, H. The charge for each pot or crucible is composed of equal bulks of ore and slack when calamine either crude or roasted is used, or if a mixture of calcined blende and calamine be employed; these, in the proportions already stated, are introduced through the apertures in the dome, the outlet in the bottom of the pot being secured by a plug of wood. The fire is then urged till the contents of the pots are brought to a full red heat, approaching to whiteness, and when the vapors arising from the ore are observed to burn with a white light, the covers are placed upon the several pots and well luted, the pipes are likewise inserted in the bottom, and the distillation is allowed to proceed, the temperature being always maintained at a high white heat. To prevent the materials in the pot from falling through, the end of the pipe is plugged with wood, but as it becomes charred, it offers sufficient space for the metal, in its passage downwards, to percolate through it without allowing any grosser matters to descend. Any metal condensed in the pipes is removed by introducing, from time to time, a small iron rod or wire, which clears it away; if this operation be neglected, the outlets are apt to get clogged up, and the tension of the enclosed gases will endanger the explosion of the covers. Usually the period occupied in a single distillation is about sixty-six hours, or five distillations in fourteen days, in which from eight to ten tons of ore are worked off, with a consumption of twenty to twenty-five tons of coal. The metal obtained amounts to thirty-five or forty per cent. of the calcined ore employed. When no more metal is condensed, the refuse matter in the pots is discharged by removing the pipe in the bottom and the cover, and then raking it out through the bottom aperture; after this operation the latter is plugged, to prepare the retort for receiving another charge. Each pot serves to distil about forty charges before it gets broken; when this happens, the fragments are withdrawn through an opening made in the surrounding brickwork, and the place of the broken pot is supplied by another annealed at a red heat in a reverberatory, as mentioned above. The collected product of the distillation, which is chiefly in drops and fine metallic powder mixed with some oxide of zinc, is melted in a large iron pot set in brickwork, and heated by a fire beneath it, when the lighter oxide and other impurities form a scum on the surface of the bath of melted metal; the former is skimmed off, and the latter cast into bars or cakes, in which state it is sent to market.

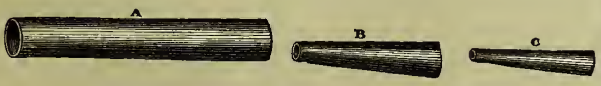
Process Practised at Vieille Montagne.—The mineral wrought at this establishment is a mixture of calamine and oxide of zinc, which is of a very compact and crystalline nature, intermixed with a gangue of clay in amorphous masses. As a preparatory operation, the mineral substance, as taken from the mine, is exposed to the air for the purpose of allowing the gangue to disintegrate, with the view of rendering its separation more easy and complete in the preparatory process to which it is submitted. There are two varieties of the carbonate treated, one of a reddish color, containing a considerable amount of iron; the other white and more compact. The ore is placed in heaps, and turned over from time to time to permit the air to pass through it more freely. After a period, varying from three to twelve months, the heap is picked, and the fragments of pure ore of the size of pigeons' eggs are selected from the rest. The refuse matter is then screened, and the coarser portions again picked out by hand; finally, the reduced fragments are washed upon the inclined plane, and the chief part of the clay is thus removed. There is a considerable difference between the periods required to disintegrate the two varieties of the mineral: by a three months' exposure the red kind is sufficiently decomposed to part with the most of its impurities, whereas the white variety takes from nine to twelve months to effect the same change; in the former the loss averages fifteen per cent., whilst in the latter it often amounts to fifty. The selected ore is then calcined, sometimes in a reverberatory, but more frequently in a conical kiln, somewhat similar in form to that in which lime is burned, and which has the advantage of being continuous in its operation. Fig. 626 represents this kiln: it is heated by two lateral fires inclosed within an arch, the products of combustion from which are draughted into the interior from a channel or flue by twenty different apertures, *o*, *o*, *o*, at various points of elevation.

Fig. 626.



The bottom of the kiln inclines towards the drawing doors, A, A, owing to the two cast-iron plates of which it is composed, *f*, *f*, being laid together at an angle of 45°, and hence the descending body of calcined ore falls in almost equal portions towards each of the rectangular outlets already mentioned. Coal is preferred for heating in this case, owing to the high temperature necessary to calcine the mass of ore which is introduced at regular intervals at the top. After drawing out the roasted ore it is ground under headstones, and sifted, so that its fineness is insured; it is then mixed with its proper quantity of combustible matter, which may be charcoal or fine coal, and introduced into the retorts for smelting. These retorts consist of cylinders of refractory clay, closed at the end which is inserted into the furnace, and open at that one which protrudes; to this end is adapted another cylinder of sheet-iron of a conical form, for the purpose of condensing the metallic vapor, and this in turn has a third pipe of the same form, but much smaller, appended to it. These several parts are seen in Fig. 627, A being the retort, B the condenser, and C the outer cone; the first is three feet eight inches in length, and six inches in diameter, the second is sixteen inches in length, and the third about the same, only that both taper, so that the aperture of the apex of C is not greater than three-fourths to one inch in diameter.

Fig. 627.



These are placed in a peculiar kind of furnace represented in elevated section in Figs. 628 and 629, the latter in the line A B of the former. The stack consists of four distinct furnaces, each in the form of a semi-cylindrical chamber, eight feet eight inches from the highest point of the arched roof to the floor, the back of the chamber being constructed so as to recede slightly from the bottom or floor upwards, as shown by *b d*, in Fig. 629, and the front, *a c*, being left open for the convenience of introducing the retorts. The fire which heats the chamber and its complement of retorts is shown at F, and is placed beneath the level of the floor of the smelting house, the combustible gases and other products passing upwards through four apertures in the grate, shown at *e*, *e*, *e*, and thence by a double flue, G, G, finding an exit overhead into the chimney, C. The latter forms one massive construction, embracing the four outlets, each closed by a damper. In each of the chamber furnaces forty-two retorts, G, G, are heated; these being placed in rows one above the other, as shown in the drawing, the posterior end resting upon a ledge made for the purpose in the masonry or brickwork. In the front the distillatory cylinders are supported by plates of cast-iron, so fixed at each side of the face of the furnace as to allow the cylinders to slope downwards from the back to the front. Before placing the retorts in this furnace, a brisk fire is maintained in it for some time, so as to bring the interior to a bright red or white heat, the face of the furnace being built up with bricks or fragments of broken retorts. When this condition has been attained, the cylinders, which should be previously heated to redness in a reverberatory, are fixed in their places one by one, the interstices between each retort at the front being closed up with fire-clay. At first, a small quantity of the mixture of ore and coal is submitted to reduction in the cylinders, the condensing cone and adapter attached and luted, and any metal given out collected in the manner presently to be indicated. These preliminary charges are successively increased for a period of three or four days, or until the furnace is found to be in a proper working condition. At this period the charge attains its mean, and consists of one thousand one hundred pounds of the roasted, ground, and sifted calamine, intimately mixed with five hundred and fifty pounds of bituminous coal in fine powder, for the forty-two retorts. This is introduced into the clay cylinders by means of a long half-cylindrical shovel attached to a long iron handle, commencing with the lower retorts, and proceeding to the higher ones in succession. When all are filled, the flue, which is usually stopped by having the damper down, is opened, and an increased firing resorted to. As the contents of the retorts attain a strong red heat approaching to whiteness, they evolve a considerable amount of carbonic oxide, which burns at the mouth of the cylinders with a bluish flame; after a while the appearance of the flame becomes more brilliant, and of a greenish white, showing that portions of the zinc vapor have been volatilized. As soon as this symptom is observed, the iron condensing tubes are attached to the open end of the retorts, the joining is well luted with refractory clay, and finally the adapters being fixed upon the condensers and luted likewise, the distillation and recovery of the zinc are proceeded with. Every attention is now given to equalize the heat in the interior of the furnace, in order that the upper retorts may be worked off equally well with the lower ones; but this result can seldom be exactly attained, and to compensate for this defect the more easily reducible ores are charged into the upper retorts, and the more refractory into the lower ones, where the heat is greatest. At intervals of two hours after the distillation commences, the outer adapter is removed by means of tongs, and the oxide of zinc, or *cadmia*, collected in it is removed, to be again submitted to the retorts in a succeeding charge. An assistant then holds a large iron ladle, called a *poêlon*, under the mouth of the condenser pipe, and the smelter rakes out the fluid zinc at the bottom of it, as well as the drops of metal attached to the sides and other parts. After carefully separating the oxide of zinc which covers the metal thus abstracted, the latter is cast into ingots, weighing from seventy-five to eighty-five pounds. The adapters are then replaced and secured as before, and after two hours the zinc produced is again removed in the manner stated.

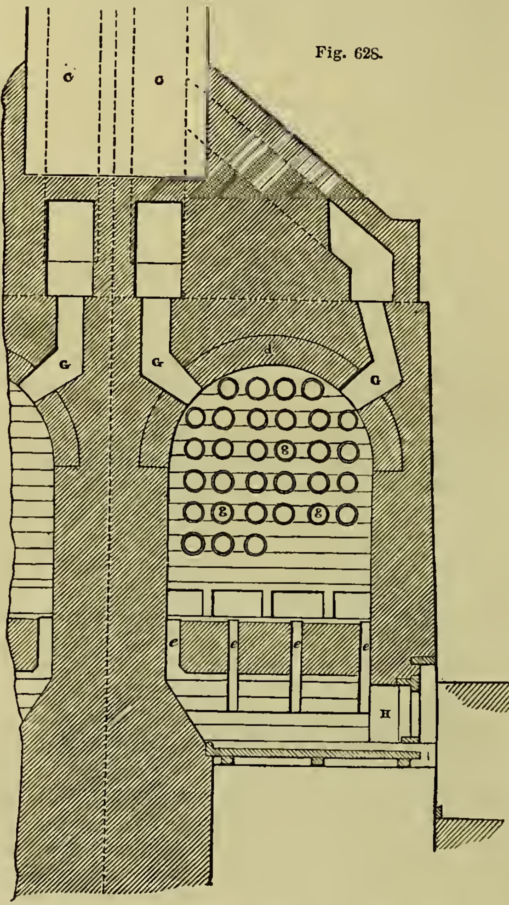


Fig. 628.

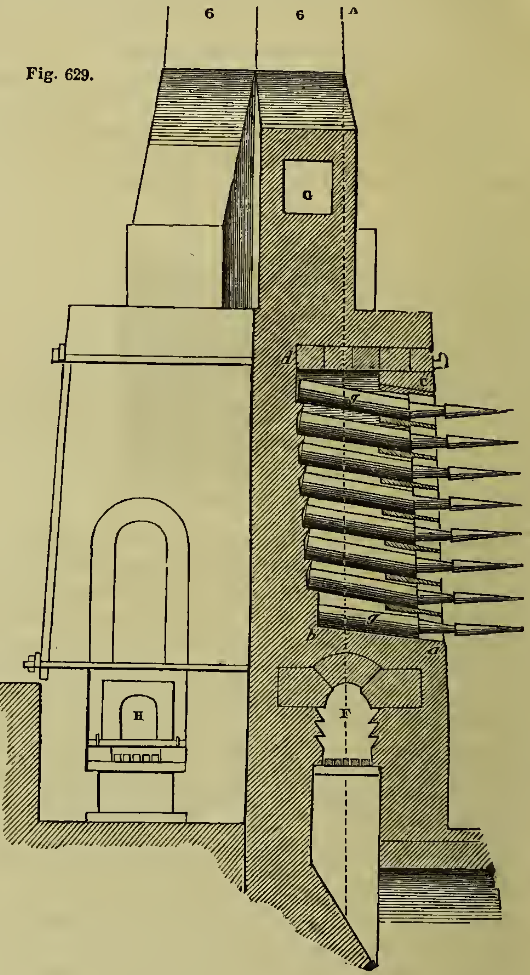


Fig. 629.

A charge of ore commenced at six in the morning, and worked in this way, is found to be exhausted of its reducible metal at five in the afternoon, so that two charges are worked in the twenty-four hours. When one operation is finished, the adapters, condensers, and retorts are thoroughly cleansed and scraped out before the next charge is introduced; and the oxide resulting from every operation and collected from the adapters and skimmings, is worked up as part of the ore of the preceding charge. The argillaceous residue cleared out of the retorts after the distillation has ended, is found to contain as much as ten per cent. of zinc; but being in the form of silicate of oxide, it resists the action of the charcoal and remains intact. About thirty per cent. of the calamine submitted to reduction is obtained in the form of metal. The distilling campaign lasts two months, during which time the fires are maintained at their greatest activity consistent with the work to be accomplished. At the end of this period, the necessity for repairs and replacing old retorts compels a cessation of the smelting for the time required to effect the necessary renovation.

Process for the Smelting of Zinc Ores in Upper Silesia.—The ores of zinc worked in this district

Fig. 630.

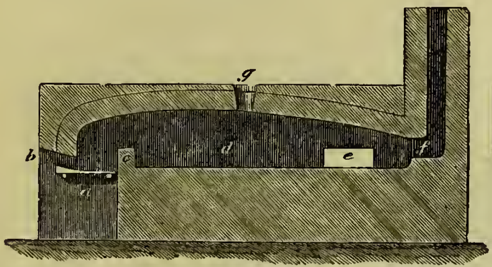
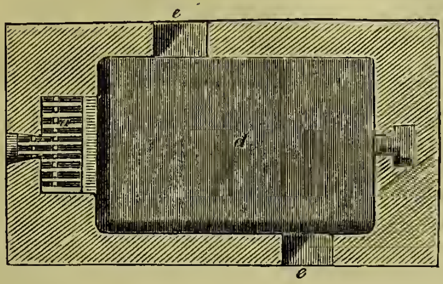


Fig. 631.

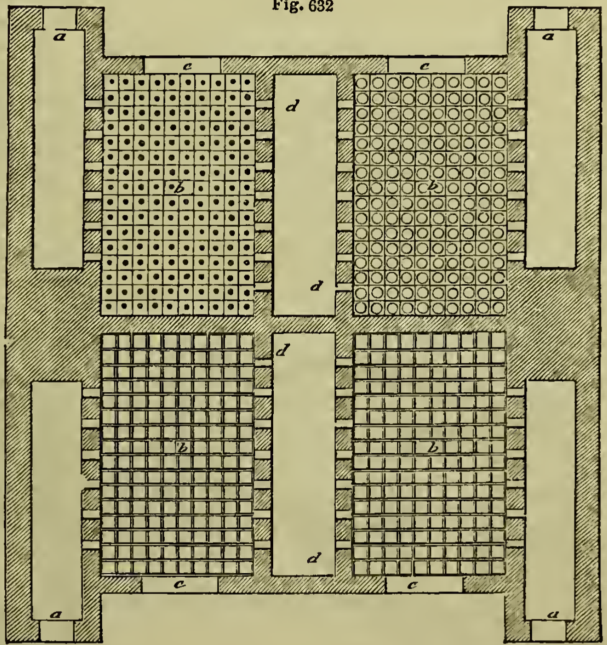


are principally a carbonate mixed with some oxide, having a calcareous and argillaceous gangue; and as the latter ingredients would materially impede the reduction of the principal compound, the oxide of zinc, they are as far as possible removed by processes of disintegration and washing analagous to those already mentioned in connection with the Belgian method.

As in the English and last mentioned smelting establishments, the purified calamine is here submitted to a preparatory calcination for the purpose of expelling the water and carbonic acid. The furnace used for this purpose is shown in Figs. 630 and 631. It consists of an ordinary reverberatory, of which *a* is the fire-grate, *b* the doors by which the fuel is introduced, *c* the fire-bridge, *d* the interior of the furnace, the bed of which is constructed of ordinary bricks, *e e* the working doors by which the charge is rabbled and worked during the calcination, *f* the flue leading to the chimney, and *g* the superior aperture whereby the ore is charged upon the bed of the furnace. The latter is lighted in the usual way, and as soon as the interior attains a strong red heat, from thirty to thirty-five hundredweight of ore are introduced at *g*, the workmen spreading it out upon the sole with rakes at the working doors; this done all the openings are closed, and the roasting is allowed to proceed uninterruptedly, with the exception of an hourly rabbling for the purpose of exposing a fresh surface of ore to the flame, till the whole of the moisture and carbonic acid is expelled. The completion of the work is judged of by the apparent heat of the interior of the furnace, the facility with which the ore falls to powder, and its change of color, which in case of the red calamine being operated upon should be brownish, and of the white calamine brownish-red. When these appearances are observed the charge is drawn, and a second, which had been placed on the platform in the interval between the charging and drawing of the roasted ore, introduced in its stead, the largest fragments from the last operation being ground and added to the fresh ore to be recalcined. Four charges are thus treated in the twenty-four hours, making a total of nearly six and a half tons of ore, which yield about seventy-two hundredweight of calcined calamine, with a consumption on an average of twenty-three bushels of fuel.

The Carinthian Process.—Here the furnaces are worked on the same principle as the English ones, but the details are different:—Figs. 632 and 633 show a plan and sectional elevation of the Carinthian furnace. As at the *Vieille Montagne* smelting works, four furnaces are connected in one block with one chimney; they consist of rectangular chambers arched over at the top, *b b b b*, heated by fires, *a a a*, from which the heated gases and flame enter by openings, *a′ a′*, to the space occupied by the retorts. Above the sole of the retort chamber, *b*, is placed a trellace work of iron, in the squares of which the vertical retorts, *p p*, are fixed by means of a clay conductor, *n*, which receives the zinc separated in the vertical cylinder. *c c c c* are the side doors affording ingress for placing the conductors and retorts in position for operations, *et cetera; d d*, outlets for the waste gases from the furnace into the flues, *e e e e*, leading to the chimney, *h*. Beneath the conductors, *n n*, is placed a flooring of plate-iron, *r r*, resting on cross supports, as well for receiving the zinc which falls in the course of the distillation as for excluding the atmosphere, and thereby preventing

Fig. 632



the reoxidation of the metal. Each of the distilling compartments admits of erecting one hundred and sixty-four vertical retorts with their conductors, but the four ranges more distant from the heat contain only empty cylinders in process of being baked by the waste heat; and even for those within the range of a distilling temperature a different mixture is made for the charging according as the cylinders are nearer to or more distant from the fire. This mixture has the following composition:—

	For the four ranges nearest the fire.	For the other two ranges.
Roasted calamine,..	1820 lbs.	520 lbs.
Wood charcoal, ground,..............	504 lbs.	224 lbs.
Common salt,.........................	36 lbs.	16 lbs.
Water charged with 1-200ths of potassa,	280 lbs.	70 lbs.

Fig. 633.

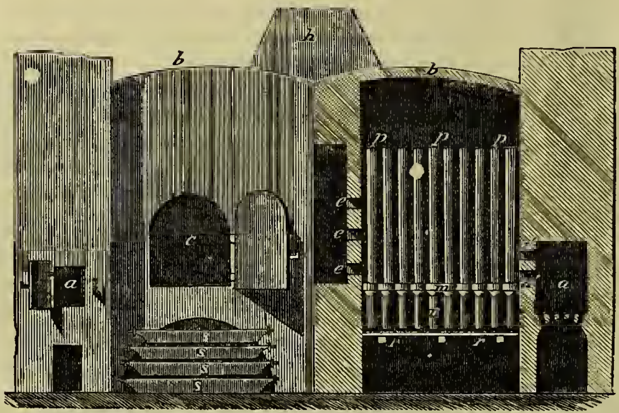


Fig. 634.

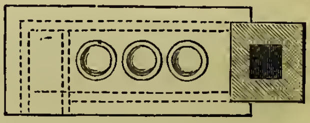
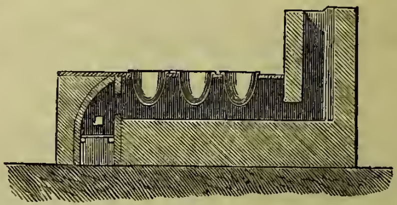


Fig. 635.



The four first ranges contain sixty-four cylinders, whereas the following two contain but twenty; the remaining spaces being left free for the passage of the products of combustion. Two adjoining furnaces are always worked together, and in these one hundred and sixty-eight cones are in operation. During the course of the distillation, which occupies thirty to thirty-six hours, the consumption of wood as fuel amounts to seven hundred and fifty cubic feet, and the proceeds average eight hundred pounds of metallic zinc.

Considerable loss of time, fuel, and retorts is incurred from the intermittent nature of the process. After collecting the metal which falls upon the plate-iron flooring, indicated by *r r*, in the foregoing figures, it is refined from oxide and other grosser impurities by fusion in pots placed in a furnace, represented in plan and section in Figs. 634 and 635. After melting the metal in the series of pots shown in these furnaces, the scum of oxide, carbonaceous matters, *et cetera*, rises to the surface, and is removed by the ladle, and the purified metal is cast into moulds for the market.

Fig. 636.

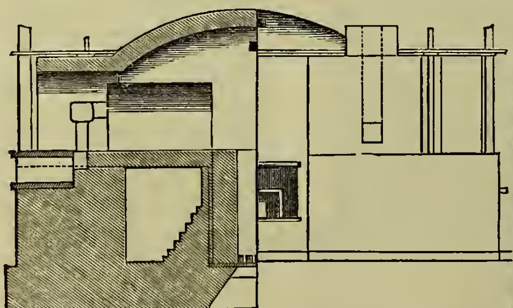
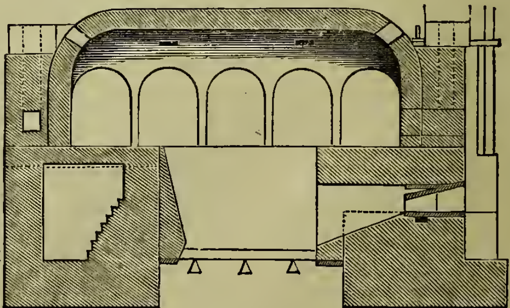


Fig. 637.



Silesian Method.—In Upper Silesia the reduction of zinc ores is carried on by a distilling process in a muffled furnace, as will be described presently. The principal seat of the smelting is in Silesia, where, in 1848, there were no fewer than thirty-five establishments for the distillation of the metal. In the Rhine Province, at the same period, there were five, and in Westphalia one. With the growing demand for zinc, however, these establishments have, during the last ten years, been enlarged and rendered more effective, so that their capacity for working is greatly increased. It may be remarked that the *materiel* of the muffles consists of fire-clay, obtained from Ruda Krzeszowitz and Kattowitz in Upper Silesia, as also from Murau in Poland, and which, after the necessary preparation, is mixed with reduced broken muffles, the whole being properly blended together to give the articles the necessary cohesion and compactness. The proportion of clay and potsherds is invariably two of the former to one part of the latter. These muffles are always made by hand, and submitted to a gradual course of desiccation, then annealed at first at a very moderate temperature, and finally at a full red heat in a furnace especially constructed for the purpose, somewhat in the manner of making glass-pots.

Figs. 636, 637, 638, 639, 640, represent the ordinary furnaces, called *double ovens*, adopted in Upper Silesia for the reduction and distillation of zinc from its ores.

Fig. 638.

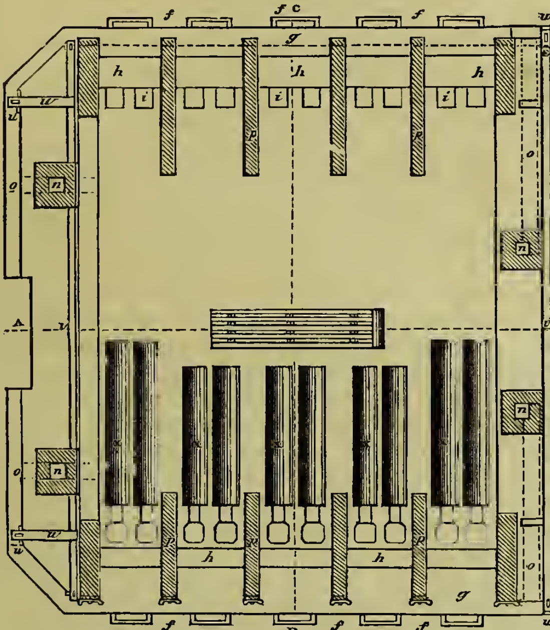
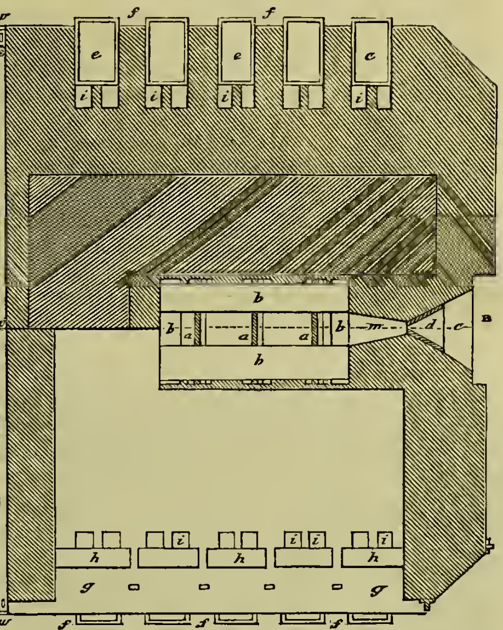
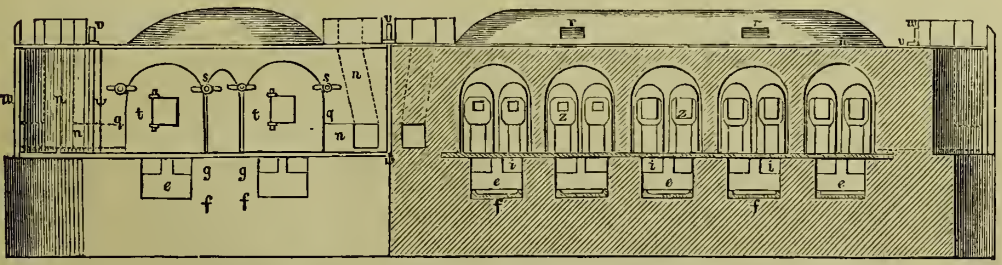


Fig. 639.



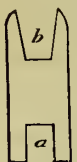
They have ten primary large chambers; but these in working are divided into twenty smaller parts, the large muffles being so constructed that the back wall is common to the two ranges. Fig. 636, is a section representing a longitudinal view to the left hand, following the line A B, and to the right the line C D in Fig. 637. Fig. 638 shows a ground plan at *a′ b′ c′ d′* in Fig. 636, and *d″ d″* in Fig. 637, in the upper half of the left side, and in the under half at *a′ b′ c′ e′* in Fig. 636, and *e″ e″* in Fig. 637. The portion to the right exhibits the furnace vertically under the dome. The same letters indicate like objects in the several figures. Three triangular cast-iron bars, *a a a*, secured at each end in the walls of the furnace, bear four iron plates, *b b*, laid transversely, to form the fire grate; the whole constituting a rose over the air channel and ash-pit. The fire-door, *c*, which is lined near the grate with a cast-iron box, *d*, is closed with a door of plate-iron, the sole of the aperture being likewise secured by a similar plate; *e e*, *et cetera*, are inclosed troughs, into which the distilled zinc trickles from the apertures of the retorts. The base of these is of iron plates, *f f*, to which deep iron bands are fixed for preventing the overflowing of the metal as it falls from the mouths of the retorts opening into them. All these receivers are closed by a single plate, *g g*, extending the whole length of the oven, and called the *hearth-plate*. They are but one foot wide, and protect, therefore, only the front part of the receivers; the interior of the latter being secured by supplementary closely fitting plates, *h h*, touching the hind part of the openings, *i i*, and towards which is the connection between the dropping aper-

Fig. 640.



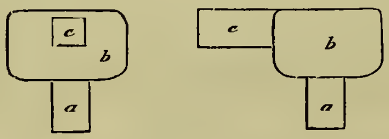
tures and receivers. These hearth-plates, in order that they may not be warped by the heat, are fastened by three cast-iron fluted anchors of the form of the letter Z. The walls, *l*, of the fire-chamber are constructed of the best fire-bricks; the connection between the fire and fire-door being an inclined canal, *m*. The upper rim of the fire-chamber is a few inches higher than the receiving troughs, so that the hearth slightly inclines from the middle to the side walls of the oven. The space between the posterior walls of the two adjoining ovens is filled with sand and rubbish; *n n* are side draughts for heating the rim muffles, and *o o* horizontal entrances for cleaning the same, which, however, are closed during the firing; *p p p, et cetera,* are pillars from three to five inches in thickness, constructed of clay, and furnished exteriorly with iron plates, *q*, secured to the hearth-plates, *g g*. These pillars form the support of the arches of the muffles which receive the retorts, as also of the overspanning dome. They should be as low as possible, so that the distance from the apices of the interior arches and the hearth be not more than three feet. The dome of the oven is constructed of a composition consisting of one-third part clay and two-thirds sand; its thickness when dry is eight or nine inches; *r r* are six cap or draught holes, by opening or closing which the heat can be directed towards any of the retorts which should happen to be working unsatisfactorily; *s s* hinges or clasps for fastening the doors, *t t*; *u* long bracing bars or anchors; *v* oblique ones, and *w* upright anchors, all applied for the purpose of giving solidity to the oven.

Fig. 641.



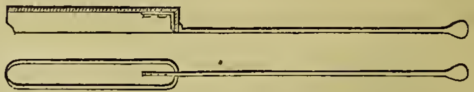
The retorts or muffles, *x x*, are set two and two within the muffle arches in the spaces between the pillars, *p p*, and placed as far back as possible, with their open faces to the front. When placed in their proper positions, the spaces between their walls and the pillars are blocked up with clay cement so as to confine the flame. The mouth of the retort is closed with a piece of clay called the bridge, *y*, and shown somewhat enlarged in Fig. 641. It has two openings; the under one, *a*, closed with a clay stopper during operations, for drawing out the residuary matter of the distillation, and the upper one, *b*, for receiving the neck of the conduit by which the vapors of zinc pass to the receivers. The latter part of the apparatus is seen in Fig. 642; the under part, *a*, is a clay pipe; the upper part consists of the head, *b*, and the neck, *c*. An opening in the head of this receiver serves for introducing the small charging shovel—Fig. 643—to spread the charge within the retort. It is closed like the opening, *a*, in Fig. 642, during the distillation.

Fig. 642.



Before the muffles are placed in the distillatory oven, they are subjected to a strong red heat in the furnace employed for annealing them. They are then placed two and two in the arched chambers of the zinc oven, and charged with a mixture of sixty-six pounds of roasted calamine and an equal volume of cinders or small coal—forming about five per cent. of the weight of the ore—together with a few pounds of oxide of zinc and abstrich or semioxydised skimmings from the collected zinc. All these are intimately mixed together before their introduction through the upper opening of the muffle bridge, the lower aperture meantime being secured with a plate and lute of clay. When charged, the neck and condenser are fixed in their places, and all apertures and cracks safely coated with luting. The iron doors in front are closed to retain the heat, and the firing proceeded with. Scarcely a quarter of an hour after the closing of the front doors of the muffles elapses when the metal begins to pass over; nevertheless the distillation is not in full activity till six to eight hours after commencing. As in the other distillatory processes already described so in this: the zinc, deprived of its oxygen by the coal in the body of the retort, passes off into the neck and head of the conduit in the form of vapor, and then condensing falls through the descending pipe into the plate-iron receivers. The combustion of a portion of the zinc cannot be avoided, as it is impossible to prevent the admission of some air into the receivers and conduits. It is owing to this, that a portion of white oxide is always found in the receivers, averaging from two to four per cent. of the metal obtained. At the close of twelve hours all the metal is extracted, and a second charge is introduced, without, however, clearing out the residue in the retort until at the end of the second operation, at which period a new bridge plate may be supplied if necessary, or any other repairs made. Care should be taken to change the muffles of both working sides of the oven every six hours after their setting in.

Fig. 643.



When the calamine contains much cadmium, it is found that the first portions of the distillate are very rich in this metal; and the oxide produced by the combustion of portions of the metal in the neck of the retort is likewise richer in oxide of cadmium, both effects being due to the volatility of the cadmium being greater than that of zinc. Six hundred pounds of roasted calamine are worked off by a furnace of ten large muffles in twenty-four hours, with charges for each retort averaging six pounds. The estimated consumption of coal per every hundred of zinc obtained is twenty-eight cubic feet; the loss of the metal is estimated at eight per cent., and of large muffles twenty-eight for every thousand pounds of zinc obtained. The average produce from the calamine operated on is about fifty per cent. in the form of metal and oxide. But as the ore varies in its content of oxide of zinc, so also does the yield. To purify the metal resulting from the first distillation, it is melted in iron pots, and the scum of oxide and other impurities separated. This amounts to eight per cent.; but as it contains about seventy per cent. of metal, and is submitted to a new reduction, a considerable amount of it is recovered.

At Kloster, where blende is worked, the apparatus and system of reduction are the same as that just described, with the exception of the roasting furnaces, in which the sulphide of zinc is converted into oxide. These are also the same as those that have been previously described, and consequently need not be further referred to.

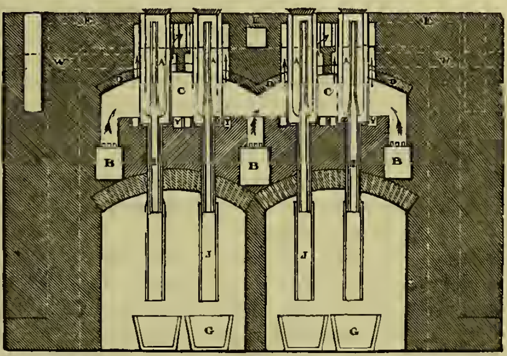
PATENT PROCESSES.—The only patents connected with the manufacture of zinc which are of any importance, are those of TROUGHTON and GRAHAM; the former sealed in 1839, and the latter in 1845. Other patents have been secured, but the Editor deems it unnecessary to dwell upon them.

TROUGHTON'S patent professed to deal with blende, and prescribes a form of furnace for the roasting, as also for the reduction. The first of these is in form like an ordinary reverberatory, with, however, three floors or hearths, on each of which the ore is spread, the heated gases and flame passing from the under chamber into the middle, and thence to the upper one, after which the gases proceed into the chimney. The connection between the several floors is made by apertures, covered by fire tiles during the roasting, but which are removed when it is necessary to transfer the ore through these openings from the upper to the lower ones. By apertures at the sides the contents of each floor are rabbled in the usual way. The charging of the ore is effected through hoppers at the top, and when roasted it is raked out into receptacles beneath the lowest hearth, by the workable openings already mentioned. A close fire, charged with fuel, which may be anthracite coal, and urged by a blast, affords the requisite heat; the opening for introducing the fuel being secured by a cast-iron cover, with a flange descending into a groove which may be kept filled with water or sand to prevent the escape of hot gases.

The fire by which the smelting of the roasted ore is effected is similarly constructed, and the combustion maintained by a blast of hot air. Though the plan as detailed in the English system is followed, yet the details are very different; the receptacles for the reception of the roasted ore and coal are constructed in the form of a trapezoid, the front part being movable when it is necessary to charge or clean out the retorts; but during the distillation it is securely luted in its place. Two ranges of retorts are placed back to back in a gallery, and the heat from the fire conducted beneath and over them by a proper disposition of the flue; and for the purpose of economizing heat, the patentee directs that the retorts be so fixed that they may be heated by a fire from both ends of the gallery. A pipe opening into the retorts, and leading to receivers in a confined arch beneath the hearth, serves to carry off the distillate or zinc. When charged and in working condition, the retorts are closed in by an iron door before each; the space above the retorts wherein the ore is previously heated, is likewise approached by sliding doors, with the view of rendering the introduction of ore and its withdrawal more easy.

In GRAHAM'S patents, sealed in 1844 and 1845, the system of distillation *per descensum* is adopted; improvements being claimed for the arrangement of the apparatus and furnace, as well as for the method of making the cylinders or retorts in which the decomposition of the prepared ore is carried out. The mixture which the patentee finds most suitable for the body of the refractory cylinders just mentioned, consists of one and a half hundredweight of Ceylon black lead; six hundredweight of Stourbridge clay; and one hundredweight of potsherds. These ingredients should be well pugged and tempered, and cut into pieces of convenient size, care being taken that no excess of moisture be used that would prevent the proper cohesion and tenacity of the mass when ramming it into the mould. Fig. 644 represents the furnace and the position of the cylinders and other objects. A, A, are a series of pots, of which the number shown in the furnace is sixteen, but more or less may be employed, according to circumstances. The heat from the fireplaces, B, B, enters into the arched chambers, C, C, and circulates round the cylindrical retorts let down through the arches, D, D, and thence into the flues, as shown by the arrows, and finally by the openings, F, F, into the chimney. The pots, A, A, rise above the arches, D, D, and pass through the covering of brickwork, E; in like manner their outlet penetrates the bed of the arched chamber of the furnace, and opens into the receivers, G G, beneath, through movable pipes, J, J, and stationary ones, I, I, the latter are constructed of iron and lined with clay, or have a movable clay cylinder fixed within them; they have an iron flange of two inches built in and through the bed of the furnace, in which is a projecting ring or groove, Z Z, to receive an iron ring that forms the projecting rim just referred to, and which fits into a corresponding depression in the bottom of the pot, and thereby forms, with the aid of a little luting, a tight joint. Y, Y are rings made of fireclay and potsherds, built into the bed of the furnace, flush on the outside, leaving a space of one inch and a half inside, as shown, to form a seat for the pot. W, W are holes in the walls of the furnace, which admit of making an inspection of the pots when necessary.

Fig. 644.



In charging the pots, the pipe, J, is stopped from beneath the furnace, and a man holds steady the internal tube, H—which has its top covered—until some of the charge is introduced; the remainder is then filled in without fear of disturbing the position of the pipe. The cover is now placed on the pot and luted, and the plug securing the pipe, J, withdrawn, and the distillation allowed to proceed by urging the fires, B, B, B. When all the metal has been drawn off, the refuse matter remaining in the pots may be cleared away by removing the cover and the internal pipe, and poking it out through the pipe, J, into the subjacent chamber.

In the other details the directions which the patentee gives are analogous to the general routine, already sufficiently described.

Mr. CROCKFORD of Holywell, Flintshire, has latterly patented a method of roasting blende preparatory to its smelting, by which all the sulphur is obtained as sulphuric acid. This he effects by employing a furnace the heat of which passes beneath the floor on which the powdered blende rests. At one end of this furnace, the blende is continually introduced in small portions at a time; and in its passage from this to the discharging end of the chamber, in addition to the heat from the floor, it is acted upon by a current of superheated air, in order to convert the sulphur into sulphurous acid. The eliminated gases may be conducted into an ordinary leaden chamber, and nitrous vapor and steam supplied from other departments in the usual way, to convert them to sulphuric acid.

After the depuration of the zinc distilled from the ore it is sold to the manufacturer, or immediately applied to one or other of the many purposes for which this metal is now so generally used. The working of zinc into useful articles was formerly regarded as a difficult operation, owing to its brittleness when worked at a high temperature; by later improvements, however, it can now be rolled and modelled into any desired shape as easily as any other metal. Preparatory to rolling the zinc, the ingots which come from the smelter are melted in pots placed in a reverberatory, such as is represented in Figs. 630 and 631. The iron pots, which are very thick, are rapidly attacked by the zinc, an alloy of the two metals being formed, which is considerably less fusible than the zinc alone, and therefore adheres to the sides of the melting pot. Besides being less fusible than zinc, it is considerably harder and more brittle, and hence, when a small quantity of it gets diffused through the metal in the casting of the plates, those portions do not laminate under the rollers, but break, and thus a hole is produced. All the fusible metal is first cast into moderately thick rectangular plates, which are passed under rollers of the ordinary kind as they cool. During the lamination it is necessary to heat the metal from time to time to a temperature ranging between 270° and 300°, passing it, after each heating, under the rollers. By repetitions of these operations, and keeping the metal as near 212° as possible, the sheets may be reduced to any degree of thinness. Sheets of zinc, manufactured in this way, are in very extensive use for roofing, and generally for applications requiring much exposure to the influence of the air. The metal is also formed into water-tanks, baths, spouts, pipes, *et cetera*, and is much used for covering or *galvanizing* iron, so as to render it less liable to oxidize when exposed to the action of the air. It is valuable for the positive plates in galvanic apparatus, for the engraver in the department known as zincography, and latterly it has been advantageously applied in the separation of silver from its alloys with lead.

ALLOYS OF ZINC.—The principal alloys of zinc are those which it forms with copper, iron, and tin. Those with copper, the reader will find described under *Brass*, in the article COPPER, and the others will be briefly described here. With iron zinc forms a hard, brittle alloy, at a moderately low temperature, but in proportion as the amount of one or other of the metals is increased, these qualities disappear, and the zinc retains its ductility, or the iron seems to acquire greater tenacity. The ductile state is exemplified in the ordinary zinc of commerce, which retains a quantity of iron, sometimes from one to two per cent., and the second or tenacious state is well illustrated by the experiments of NASMYTH upon galvanized iron, the results of which showed that this alloy welds well, and is not only fully as ductile as the best iron, but acquires greater strength or tenacity.

The experiments were made with some zinced wire rope, which was worked up and welded into a bar. It was observed that, although the iron wire was quite covered with the zinc, the portion of the latter metal which was retained at the welding temperature of the iron, or even the portion of oxide of zinc produced, offered no impediment to the welding. The metallic bar produced was remarkably tough, silvery-grained, and withstood punching, twisting, splitting, and binding, in a manner which showed that the iron was not only excellent, but actually improved in quality in a considerable degree. Another trial was made by welding a pile of clippings of zinced iron plates, as in the preceding experiment. The presence of the zinc seemed to offer no impediment to the welding of the iron, and the bar produced presented, on being fractured, a beautiful silvery grain, as good, if not superior, in aspect to the finest samples of *low-moor*, or *bowling* iron. Bars or *blooms* of the alloyed iron, rolled into rods and tested in the cable-proving machine, indicated from five to ten per cent. more strength than the best samples of wrought-iron; thus evidently showing that, so far from being injurious, a small amount of zinc alloyed with iron has the contrary effect. Bars of iron, prepared according to the last-mentioned process, were heated to the temperature of welding, as when converting them into sheathing in the usual manner, on drawing them from the fire, a handful of zinc filings was thrown on the welding surface, and the welding proceeded with. In this severe test no apparent impediment to the process resulted, the iron welding as well as if no zinc were present. Judging from the appearance of the metal welded up from the zinc-covered iron scraps, not only as respects its clear silvery aspect, but as to the increase of strength which it exhibited under proof, it may not be unreasonable to infer that some important improvement might be made in the manufacture of iron by the actual introduction of metallic zinc in some one or other of the stages of its production; as, for instance, in the puddling furnace. What may be the nature of the action of the zinc has not yet been defined, but the foregoing experiments prove that, so far from being prejudicial to the quality of iron, the zinc appears to have rather an improving effect, and that to such an extent as to lead to the hope that some of the intelligent iron manufacturers may give the inquiry attention, so as to prove by experiment in the puddling furnace, or at any other stage of the process, whether the benefits above mentioned can be realized on a large scale. It may be stated, as a curious corroborative fact, that the strongest cast-iron made in Belgium, and selected for the manufacture of guns, is made from an iron ore in which a compound of zinc forms a considerable portion. Whether the superiority of this iron is due to the presence of zinc, is a question; but the results above detailed would tend to lead to the supposition that such may be the case.—*Ure.*

The results of **Nasmyth**, recorded above, are opposed to those of **Gehlen**, who states that when cuttings of zinc and iron are ignited together, part of the zinc evaporates, while the rest penetrates the iron and makes it denser and very brittle. Doubtless the difference in the results must be attributed to the relative proportions of the respective metals in the alloy. The hard, brittle compound of zinc and iron produced in the pots where zinc has been melted for a long time, or in which the zincing of iron plates has been effected, was examined by **Berthier**, who describes it as a bright crystalline body, having a mammillated texture, and composed of concentric layers, very hard and brittle, and less fusible than pure zinc. It dissolves readily in dilute nitric acid, and leaves a micaceous residue of a non-metallic nature, which he terms pure plumbagine, produced, doubtless, either from the carbon employed in the reduction of the zinc ores, or from the cast-iron of the pot. Its density was 6·7, and its composition—

	Centesimally.
Zinc,	94·76
Iron,	5·00
Plumbagine, or graphite,	0·24
	100·00

Galvanized Iron.—The composition which forms such an extensive article of commerce and general application in the construction of corrugated roofing, and, in fact, entire buildings, spoutings, ships' sheathing, buckets, and various articles in household use, consists of iron plates coated with zinc, and sold under the above inappropriate title. Iron, though possessing so many admirable qualities, such great tenacity, infusibility, and the very important one of welding, is, unfortunately, rapidly acted upon by air, moisture, and dilute acids, to such an extent as greatly to impair its utility. It possesses the property, however, of oombining with other metals, and hence it can be readily coated with such; but those metals which possess the persistent qualities that iron wants, are too dear, and therefore their general application is opposed by the great expense which their use would involve the manufacturer and consumer. Coated iron is familiar to most people in the form of tinned iron plates, or *sheet tin;* but even this material would be too expensive for many of the applications in which iron might be employed with advantage could its oxidizing tendency be overcome. Zinc offers a cheaper substitute, and of late years the production and application of galvanized iron is on the increase. Although **Melouin** discovered the method of preparing zinced or *white* iron so early as 1742, still its application did not receive much attention, till of late years **Sorel** drew attention to the manufacture; but **Melouin's** directions, with slight modifications, are followed even at present in the manufacture of this article. The iron to be covered is deprived of its coating of oxide by an acid bath, composed of sulphuric acid and water, or of hydrochloric acid, or a mixture of equal volumes of the two acids and water, in which it is immersed for a short time; it is then scrubbed with sand or emery powder until the surface is cleaned; after which it is immersed in a concentrated solution of chloride of ammonium, taken out, and subsequently introduced into a bath of melted zinc, covered with fatty matter, or colophony, to prevent oxidation, and stirred in it till the zinc forms an alloy at its surface. The coated metal is then, in some instances, introduced into a second bath consisting of melted tin, such as is used for tinning thin sheet-iron, when a slight coating of tin is formed on the exterior of the plate or bar. Of late years this second bath is generally dispensed with, a few pounds of tin being added to the zinc bath to produce the same effect.

According to **Mallet's** specification, the plates or bars are immersed in a cleansing bath, composed of equal parts of sulphuric acid, hydrochloric acid, and water in a warm state. After immersion the scales are detached by hammering and scrubbing the plates with emery and sand, and a thoroughly clean surface produced. It is now to be immersed in the preparing bath, composed of a saturated solution of chloride of zinc and sulphate of ammonia; after which it is transferred to a bath formed of six parts and a half of zino and one of mercury, heated to the melting point of the former metal; in addition to which the patentee directs the addition of one pound of potassium or sodium to every ton of the preceding amalgam. When the immersed iron has attained the temperature of the bath, namely, 680°, it is withdrawn, and is found coated with a metallic layer, of which zinc forms the principal constituent. The affinity of the above alloy for iron is so great that it entirely disintegrates the iron plates, or other articles of this metal when they are thin, or possess but little body; and to guard against this inconvenience, the patentee suggests that some wrought-iron should be allowed to dissolve in the triple alloy previous to the introduction of small articles, such as wire, nails, light chains, and similar objects for galvanizing. Another means of coating iron with zinc is by electricity, and the use of a bath formed by the solution of freshly precipitated oxide of zinc in a saturated aqueous solution of sulphurous acid, or of that of the double chloride of zinc and ammonium. A moderately dilute bath and a weak current answer best. This method is not advantageous in a manufacturing sense, the simpler mode of immersion being more expeditious and less costly.

Though iron coated with zinc is unquestionably better calculated to resist atmospheric influences without rusting than when it is without such covering, still zincing it is very far from being a uniformly successful protection against its oxidation, and in some cases it increases rather than diminishes this tendency of the iron. Professor Callan proposed an alloy of lead and antimony as a substitute for the zinc; but though the disadvantage experienced in many instances as resulting from the employment of zinc are certainly diminished by the use of the alloy, still the cost of the latter precludes its adoption.

Applications of Zinc.—Besides its long-practised application in the production of brass and other alloys, such as German silver, tutenag, *et cetera*, which the reader will find described under Copper, zinc has been employed extensively in the form of sheets for the manufacture of baths, water tanks, buckets, pails, roofing, spouts, pipes; as a cheap and more durable substitute for sheet and japanned iron, such as architectural ornaments, street lamps; and for making nails, bolts, wire for preserving iron, applied in the form of wire plates to the numerous uses which are everywhere to be witnessed; as a substitute for bronze in statuary, for which purpose it has been found, irrespective of its color, to answer exceedingly well. It is also extensively employed for the positive plates of electrical batteries, for engraving music, in anastatic printing, and numerous other forms, alone and compounded with other metals. In its oxidized and salified state it has another extensive field of application, both in the industrial arts and in medicine, as will be noticed afterwards.

Assay of Zinc Ores.—The estimation of the amount of zinc in any of its ores by the dry method of analysis, is exceedingly difficult. As, however, the metallurgist may desire to have an approximation of the quantity of metal which he can probably extract from any ore, the following brief statement of the operation is submitted here, reserving fuller instructions for the analysis of zincous bodies in general for the end of the article.

Berthier, who has made numerous experiments on the subject of the assay of zinc ores, divides the latter into four classes, for each of which a particular method must be pursued. These are, firstly, ores in which the zinc exists as *oxide*, or *carbonate of the oxide;* secondly, those in which the zinc exists wholly or in part as *silicate of the oxide;* thirdly, ores in which the zinc is entirely or in part in the form of *sulphide;* and fourthly, *alloys* of zinc.

To reduce ores of the first class, it is only requisite to mix them intimately with charcoal, and expose the assay for a sufficient time to a white heat in an earthen retort, having a long neck kept sufficiently cool to condense the metallic vapors that are expelled by the heat from the reducing mass. Care must be taken that no air be admitted into the retort, for this would induce the combustion of the metal while in a state of vapor; its neck should therefore terminate in a small opening, or an adaptor of glass drawn to a point be fixed to it by luting. During the reduction the following simple interchange takes place:—

$$\underbrace{ZnO}_{\text{Oxide of zinc.}} + \underbrace{C}_{\text{Carbon.}} = \underbrace{Zn}_{\text{Metal.}} + \underbrace{CO}_{\text{Carbonic oxide.}}$$

Even when the reduction is thoroughly effected, it is most difficult to detach the incrustation of metal sufficiently complete for accurate determination. To facilitate this the neck of the retort is coated interiorly with plumbago to diminish the adhesion of the distilled zinc to the body of the apparatus. When all the metal is reduced and driven over, the assayer is often necessitated to break off the neck of the retort to enable him to collect the metal, and not unfrequently to dissolve the adhering particles with nitric acid, and evaporate and calcine the residue, adding the four-fifths of its weight to that of the metal already estimated.

Another process by which the estimation of the zinc may be indirectly made is given as follows:—A certain portion of flux is added to the weighed ore, submitted to the test, and the whole heated at the temperature at which the assaying of iron is usually conducted in a lined crucible. The button of slag containing granules of iron resulting from the ferruginous matter in the ore, is weighed, then ground in a mortar, and the iron, separated by a magnet, likewise weighed. After deducting the iron thus estimated from the total weight of the button of fluxed matter, the remainder is added to the oxide of iron, corresponding to the amount of this metal found as above. The combined weight, deducted from that of the dry ore and flux, leaves a difference corresponding to the zinc expelled during the assaying in the fire. Again, if the quantity of the fixed flux employed be taken from the weight of the button of slag obtained minus the iron, the difference will show the silicious, earthy, and other unreducible matters associated with the zinc.

In the examination of ores of the second class, charcoal alone is insufficient to effect the decomposition, and therefore a flux is employed which, by combining with the silicious matter, liberates the oxide of zinc, and renders it subject to reduction by the carbonaceous matter. Lime or magnesia are the agents usually adopted.

When ores of the third class are under examination, the weighed sample is roasted, to convert the whole of the sulphur into sulphuric acid and partly expel it by the heat; after which the reduction is effected in the same way as directed for the determination of the metal in the first class of ores.

Alloys of zinc with fixed metals, or the compounds of the fourth class, are examined by adding a determined weight of fixed flux, mixed with some charcoal, and heating in a lined crucible at the temperature of the iron assay; all the zinc is volatilized, and from the loss of weight so sustained the amount of zinc is estimated approximatively. If the alloyed metal be of a volatile nature, this course will not afford true results, and the estimation of the constituents of the compound must be effected by the humid assay, which indeed is the most trustworthy, and in the end the most expeditious for the analysis of all zincous compounds.

COMPOUNDS OF ZINC.—Zinc is capable of uniting with almost the whole of the metalloids and salt radicals, producing compounds, which in all instances are of great importance in the arts, and have consequently a very extended application. Its oxygen salts, like those of magnesia, have the property of forming saline compounds with other substances, the importance of which is entirely confined to the department of scientific chemistry connected with stoichiometry. Another remarkable behavior of zinc is, that it readily combines with several organic radicals, such as ethyl, methyl, and radicals of the alcoholic series of compounds, as shown by the very scientific researches of **FRANKLAND** and others. Several of the combinations of this metal are employed in medicine; and, by a remarkable coincidence, these so employed are most useful in many industrial applications. It will be sufficient to describe here the oxide, the carbonate, sulphate, acetate, and chloride of this metal.

OXIDE OF ZINC.—This compound has various designations, most of them given by the alchemists. Its ancient synonyms were *nihil album*, *lana philosophica*, *flowers of zinc*, *pompholyx*, and occasionally it is still known as *flowers of zinc* or *flores zinci*. When submitted under certain circumstances to the influence of air and moisture, zinc is acted upon in various ways, all of which result in producing the oxide, or a compound from which the oxide can be readily prepared. Thus, when the metal is heated to redness in a free current of air, it burns with a brilliant bluish-green flame producing oxide of zinc. Again, if the zinc be exposed to air and moisture, it is transformed into the same compound; or if carbonic acid should be present, into a basic carbonate of the oxide. In these cases, simple and direct oxidation takes place, the oxide combining, in the latter instance, with a certain amount of carbonic acid. This is the nature of the change which is produced on the surface of zinc exposed to the air, as in roofings, *et cetera*, and which conduces so much to its preservation. It is illustrated by the following equation:—

$$\underbrace{5\,\mathrm{Zn}}_{\text{Metallic zinc,}} + \underbrace{\mathrm{O}_5}_{\text{Oxygen.}} + \underbrace{2\,\mathrm{CO}_2}_{\text{Carbonic acid,}} = \underbrace{\mathrm{ZnO},\ 2\,\mathrm{ZnO},\mathrm{CO}_2}_{\text{Basic carbonate of zinc.}}$$

When zinc is dissolved in sulphuric or nitric acid, the oxide is freely formed, though only in the proportion requisite to produce a salt with the acid employed. In this state it exists in the salified state, but on abstracting the acid by interposing a stronger base, such as soda, the hydrated oxide falls, thus—

$$\mathrm{ZnO,\ SO_3 + NaO,\ HO = NaO,\ SO_3 + ZnO,\ HO.}$$

The same change takes place when the solution of zinc in hydrochloric acid is acted on, although the oxide does not pre-exist in the menstruum, for at the period of the removal of the radical of the salt the oxygen of the precipitant is assimilated by the zinc, as shown in the equation—

$$\mathrm{ZnCl + NaO,\ HO = ZnO,\ HO + NaCl.}$$

Oxide of zinc is prepared either by the ignition of the metal in a current of air, or by its solution in acids and subsequent precipitation by any convenient agent. If pure oxide be required, the first method will not yield it unless the metal be free from all extraneous metalliferous matters, which is never the case with the commercial article. In the second method the impurities existing in the zinc can be removed previous to the precipitation of the oxide, and consequently this method is preferred when it is important that no foreign matter should exist in the preparation.

In operating by the first method, a hessian crucible is filled with zinc to one-eighth its capacity, and then placed in a wind furnace so inclined that the lower part rests upon its edge on a piece of tile at the bottom, whilst the upper part is supported by the rim of the furnace. The fire is then urged till the crucible and contents attain a strong red or white heat. At this period a scum of oxide appears on the metal, and must be removed with an iron spatula as fast as formed, till the combustion of the zinc is completed, when a fresh charge may be introduced. The oxide as collected is placed upon an iron plate to cool, and is afterwards rubbed up with water to the consistence of a thin pasty mass, which is next diluted largely, allowed to settle for a few minutes and then decanted, more liquid being agitated again with the subsided matter, and treated, after a minute or two's repose, in the same manner. By continuing the treatment so long as the decanted liquors flow off milky, all the oxide is separated from the metallic matter which escaped ignition in the crucible, and which may be introduced with another portion of zinc to undergo fresh combustion. All the decanted liquors are collected together and allowed to subside perfectly, when the clear water is poured off, the deposit thrown upon a cloth filter to drain, and finally it is dried at a gentle heat. The yield of zinc oxide obtained in this way, when the whole of the metal is burned, will be somewhat more than the weight of the zinc employed.

When the oxide is to be prepared by the liquid process, rectified sulphuric acid, diluted with ten times its weight of water, is poured upon the zinc previously rolled into thin sheets, or granulated by pouring it whilst in a molten state into a vessel of water, employing an excess of the metal with the view of causing the foreign matters, such as lead, tin, cadmium, bismuth, arsenic, *et cetera*, to be precipitated; or a solution of crystallized sulphate of zinc in thirty parts of water may be taken, immersing in it for forty-eight hours a few thin plates of zinc, which act in the removal of any foreign bodies in the same way as the excess of metal in the foregoing method. The clear solution is decanted in either case, or strained, if necessary, and a hot concentrated solution of carbonate of soda is added to it as long as a precipitate forms. This precipitate, which settles much more readily when thrown down from hot solutions than from cold ones, is now washed with hot distilled water by decantation, till no further trace of sulphuric acid is detected in the washings with a solution of chloride of barium. After thorough washing it is collected on a cloth filter, allowed to drain, pressed and dried, and finally heated to redness in a hessian crucible, till the whole of the carbonic acid is expelled, as evidenced by its not effervescing on the addition of dilute acid.

Properties.—Oxide of zinc is a white, tasteless, inodorous powder, which at red heat acquires a yellow color, that vanishes on cooling. When subjected to a higher heat it melts into a yellow glass, and at a sustained white heat volatilizes. It is insoluble in water, but readily soluble in acids, giving rise to the corresponding zinc salts. When freshly precipitated, oxide of zinc is readily soluble in alkaline solutions, as also in concentrated ones of sesquicarbonate of ammonia, producing compounds in which it assumes the characters of a salt radical that are called *zincates.* Heated with charcoal it is readily reduced to the metallic state.

Uses.—Oxide of zinc is employed principally in medicine. Latterly, however, it has been successfully introduced as a substitute for carbonate of lead—white lead—in the manufacture of paint; and to meet this extended use several processes have been devised for its preparation, to which reference will be made presently. The oxide has been prescribed in some cases of epilepsy, chorea, hysteria, catalepsy, and hooping-cough, as well as in some painful affections of neuralgia and gastrodynia, with occasionally good effect, though its frequent failure has shaken the confidence of practitioners in its efficacy. It has been found serviceable in five-grain doses, combined with extract of henbane or hemlock, in colliquative perspiration. It is useful as a desiccant to allay or prevent excoriation in children, as well as in cases of chronic skin diseases, attended with profuse secretion, and also in other ailments of a similar nature. In large doses, oxide of zinc acts as a slight irritant and causes vomiting, and by long-continued use it acts as a slow poison.

Oxide of zinc is composed of—

	Atomic weight.		Centesimally.
1 Eq. of zinc, ...	32·0	....	80·0
1 Eq. of oxygen, ...	8·0	....	20·0
	40·0	....	100·0

Its chemical symbol is ZnO.

CHLORIDE OF ZINC—*Muriate of zinc; butter of zinc.*—This compound of zinc has long been known and applied in medicine. It is prepared by adding hydrochloric acid of specific gravity 1·130 to granulated zinc portionwise, and applying heat till the latter is dissolved. Four parts and a half of acid are required for every part by weight of metal for its perfect solution. A few fragments or thin plates of zinc are introduced into the solution, and set aside for twenty-four hours, during which time any lead, tin, antimony, cadmium, or other metals of this class that may be present in the liquid, are precipitated; after this, the clear liquid is separated by filtration from the deposit that may have formed, and about one-sixteenth of its bulk precipitated, with a very slight excess of carbonate of soda, the basic carbonate separated and well washed while on the filter, and then introduced into the remainder of the liquid. Chlorine, generated in the usual way from binoxide of manganese and hydrochloric acid, is now passed into the menstruum till it smells of the gas. A further period of twenty-four hours is given to the liquid to stand, and if, after this period, a portion of the clear solution exhibits any indication of the presence of iron, either by giving a bluish-black color with tincture of galls, or by striking a deep blue with ferricyanide of potassium—red prussiate. A further portion of the liquid is taken and precipitated with carbonate of soda, as above, and the mass so obtained, after thorough washing, is added to the liquor containing the zinc, allowed to digest for a further period, and afterwards tested for the presence of iron in the manner indicated. If necessary, the process is to be repeated a third and a fourth time, or until the whole of the iron is separated in the form of sesquioxide; but it rarely happens that this metal remains after the second digestion. After filtering from the formed deposit, the liquid is evaporated in a porcelain or hard stoneware dish on the sand-bath, taking care, as it becomes denser, to keep the contents of the vessel constantly stirred, till the whole of the water is expelled. Chloride of zinc remains, and should be transferred, whilst still hot, to well covered vessels for use. When it is necessary to deprive it of the whole of the water, the residue from the evaporation should be introduced into a glass vessel with a narrow neck, and heated at a higher degree, till the chloride of zinc begins to distil, at which period the fused matter is poured out on a slab, and when cooled broken into fragments, and preserved in well-stopped bottles.

In the preceding process the action of the acid is simple and well understood, its chlorine uniting with the metal, while its hydrogen is disengaged, thus—

$$Zn + H\,Cl = Zn\,Cl + H.$$

The action of the chlorine is to convert the iron, which always exists in commercial zinc, from the state of protochloride to which the hydrochloric acid reduces it, to that of sesquichloride, as shown in the equation—

$$\underbrace{2\,(Fe\,Cl)}_{\text{Protochloride of iron.}} + \underbrace{Cl}_{\text{Chlorine.}} = \underbrace{Fe_2\,Cl_3}_{\text{Sesquichloride of iron.}}$$

with the view of precipitating it subsequently with the basic carbonate of zinc—3 (ZnO, HO) 2 (ZnO, CO_2)—produced by the carbonate of soda in the portion of the liquid submitted to its action. The manner in which its separation is chemically effected may be represented thus—

$$\underbrace{5\,(Fe_2\,Cl_3)}_{\text{Sesquichloride of iron.}} + 3\,\underbrace{(\,3\,(ZnO,\,HO)\,2\,(ZnO,\,CO_2)\,)}_{\text{Basic carbonate of zinc.}} =$$

$$\underbrace{5\,(Fe_2\,O_3)}_{\text{Sesquioxide of iron.}} + \underbrace{15\,Zn\,Cl}_{\text{Chloride of zinc.}} + \underbrace{6\,CO_2}_{\text{Carbonic acid.}} + \underbrace{9\,HO}_{\text{Water.}}$$

that is, three equivalents of the basic carbonate convert five of the iron salt into five equivalents of insoluble sesquioxide, being themselves reconverted into fifteen equivalents of the chloride of zinc by the assimilation of the chlorine from the iron compound.

Chloride of zinc may be prepared by other processes, such as heating equivalent weights of oxide of zinc and chloride of ammonium, or by distilling a mixture of dry sulphate of zinc and chloride of sodium in a retort, the substances being employed in the ratio of their equivalent weights. In either case chloride of zinc results, the change in the former being $NH_4\,Cl + ZnO = NH_4\,O + Zn\,Cl$; and, in the latter, $ZnO,\,SO_3 + Na\,Cl = Zn\,Cl + NaO,\,SO_3$. The salt in the first formula remains after the expulsion of the ammonia; but in the second instance it distils over, leaving the sulphate of soda in the retort. Preference is, however, generally given to the method of preparation by solution.

Properties.—Chloride of zinc, deprived by fusion of all moisture, is a whitish-grey, semitransparent soft mass, like wax, that melts at a temperature below redness, and at a higher degree of heat sublimes, being at the same time partially decomposed into a basic chloride of zinc and an acid salt, which collects in crystalline needles in the receiver, and oxide of zinc retaining a little of the chloride that remains in the retort. Exposed to the air, the salt rapidly attracts moisture and deliquesces. It has a burning, nauseous, saline taste, even in highly dilute solutions. Alcohol and ether readily dissolve it, the solutions manifesting an acid reaction. It unites with chloride of ammonium and chloride of potassium, and forms definite compounds with them, likewise with albumen and gelatin, producing difficultly soluble precipitates. The alkalies and alkaline carbonates decompose it, giving rise to precipitates of oxide and basic carbonate of zinc, according to the agent used, but which precipitates, as stated under *Oxide of Zinc*, are soluble in an excess of many of these reagents, owing to zincates of those bases being formed. Sulphuric acid readily converts the chloride into a sulphate of zinc, with evolution of hydrochloric acid. The pure salt has a composition corresponding to the symbol Zn Cl, being composed of—

	Atomic weight.		Centesimally.
1 Eq. of zinc,...............	32·0	....	47·407
1 Eq. of chlorine,...........	35·5	....	52·593
	67·5	....	100·000

The composition of the hydrated salt is Zn Cl, HO; it is crystalline, and contains, according to SCHINDLER, in one hundred parts—

			Centesimally.		Schindler.
Zinc,.......	32·0	=	41·83	....	39·80
Chlorine,....	35·5	=	46·40	....	43·81
Water,......	9·0	=	11·77	....	16·39
	76·5		100·00		100·00

Uses.—Owing to its physiological effects, the chief use of chloride of zinc is in medicine; but latterly it has been successfully introduced as a disinfectant, and likewise for impregnating wood in order to preserve it from decay or putrefaction. Its use has been much extended in the first application by its qualities as a caustic or escharotic, destroying the life of the part with which it comes in contact, owing to its combination with the albumen and fibrin of the tissue, which substances appear in the form of an eschar some time after. Many prefer chloride of zinc in this capacity to nitrate of silver, and even to chloride of antimony, as it penetrates further, and leaves the wound or sore in a more healthy state after the removal of the eschar. When taken into the system, chloride of zinc acts, in large doses, as an irritant or caustic poison, and affects the nervous system. It produces a burning sensation in the stomach, nausea, vomiting, anxiety, short breathing, cold sweats, fainting, and convulsions. In very small doses, none of these effects are attendant upon its use.

Sir WILLIAM BURNETT introduced a concentrated solution of this compound some years ago, as a disinfecting and antiseptic fluid. The liquid contained about one-fourth of its weight of the salt, and had a specific gravity of 2·0. Its antiseptic qualities depend upon its power of uniting with animal tissues, and forming permanent bodies with them; and hence its use in preserving anatomical subjects for dissection; its disinfecting quality arises from its power of decomposing sulphide of ammonium and sulphide of hydrogen to some extent. It is inferior, however, in this respect to a solution of chloroxide of calcium—bleaching powder—and several other combinations, as stated under *Disinfectants*—owing to the latter being not only capable of arresting gaseous emanations, but also of disseminating a disinfecting gas into the air which arrests any foul odor immediately.

SULPHATE OF ZINC—*Zinc vitriol; white vitriol.*—This salt, which is said to have been known at the end of the thirteenth century, has been long manufactured on a large scale at Goslar in Germany. It was long erroneously considered as a modified sulphate of iron, but this notion was abandoned when the true metallic nature of zinc became known. It is much more important than any other saline combinations of the metal, as well for its cheapness as for being the means of preparing the other compounds of zinc, and likewise for the extended uses to which it is applied in the arts and in medicine.

Preparation.—At Goslar, where sulphate of zinc was first extensively manufactured, as well for the preparation of Nordhausen vitriol as for application in the medicinal art, the following process was adopted:—

The natural deposit of ore, consisting of sulphates of zinc, lead, copper, silver, and iron, was assorted to obtain the portions richer in zinc; these were submitted to a roasting operation in heaps, during which the sulphur was converted into sulphuric acid, and by this the metals were changed into the corresponding sulphates; the mass was then lixiviated, and the soluble salts, consisting of sulphates of zinc, iron, cadmium, copper, and silver, washed out, and afterwards evaporated till the sulphates crystallized. The impure salt, after slight washing, was heated to the melting point, and the whole, or chief, part of its water of crystallization expelled. On allowing the mass to cool at this stage, it formed a white opaque granulated substance resembling sugar. At a later period this product was freed from portions of its impurities by re-solution in water, and introducing into the lie fragments or plates of zinc, which were allowed to remain in contact with it for a longer or shorter time. After drawing off the clear liquid, it was evaporated, and the zinc salt crystallized out as before. This method is still practised, not only at Goslar, but in several other localities where blende is abundant.

Sulphate of zinc is obtained at present as a secondary product from the acid liquors of galvanic batteries employed in developing electricity, as also from the liquors remaining after the precipitation of copper on the large scale from its solutions, by metallic zinc.

The pure salt may be obtained by treating commercial, or purified zinc, in a divided or granulated state, with sulphuric acid diluted with fifteen times its weight of water, in a leaden vessel, using the acid while still warm; three parts of rectified acid of specific gravity 1·84, are required to convert two parts of the metal into a sulphate. The mixture is sustained at a gentle heat in order to promote the solution, and with the same view the contents of the vessel are agitated occasionally. After the solution is effected, a quantity of metal, about one-eighth of the portion dissolved, is introduced into the liquid, and left to repose during thirty to forty-eight hours, the slight heat being still maintained. By this treatment the lead and other less oxidizable metals are precipitated, and are separated by filtering the liquid while still hot. The filtrate is now largely diluted with water, and a portion of it taken, precipitated with carbonate of soda, as stated under the preparation of chloride of zinc, filtered, washed, and added to the remainder of the solution of the sulphate. Chlorine is then transmitted into the mixture till the protosalt of iron present in it is converted to a sesquisalt; after which the whole is allowed to stand till the iron falls in the form of sesquioxide. The various changes by which the purification of the salt is effected in this instance, are analogous to those specified under *Chloride of Zinc*, and therefore need not be detailed. After filtering the liquid from the deposit of sesquioxide of iron, it is evaporated till a pellicle begins to form on the surface, when it is permitted to rest to allow the salt to crystallize. A second crystallization removes all traces of impurities, but this is rarely required.

Properties.—Sulphate of zinc crystallizes in colorless, transparent, right rhombic prisms, containing seven equivalents of water of crystallization. In this state it is very soluble in water, requiring somewhat less than its weight of cold, and considerably less than its weight of the boiling liquid; thus, according to Karsten, one thousand parts of water at 63·6°, dissolve nine hundred and twenty-three parts of this salt, forming a solution, the specific gravity of which is 1·4353. Dumas states that one hundred parts of water, at the ordinary temperature, take up one hundred and forty parts of the sulphate; while other authorities assert that not less than two and one-third parts of water are necessary for the liquefaction of one of the salts, which is evidently erroneous. Boiling water takes up a much larger quantity of the salt, and even alcohol dissolves traces of it. Sulphate of zinc, according to the circumstances under which it is prepared, is found associated with different quantities of water of crystallization, varying from one to seven equivalents; but the compound crystallizing from its solutions at temperatures below 80° to 86°, always assimilates seven equivalents of water. This salt effloresces slightly in the air; exposed to a heat of 212° it loses 37·3 per cent. of moisture, or six equivalents, the last equivalent being obstinately retained till the heat rises to 451°. By the sudden application of a high temperature the compound at first fuses, and after the expulsion of the contaiued water, decomposition of the salt follows; anhydrous sulphuric acid, sulphurous acid, and oxygen being eliminated, while a highly basic salt remains. On continuing the heat, however, till it approaches to whiteness, only pure oxide of zinc is left. Heated with charcoal at a red heat, it is reduced to the form of sulphide; but at a sustained white heat, the metal is isolated and volatilized in the form of vapor. Anhydrous sulphate of zinc, on being exposed to moist air, readily assimilates its full complement of water of crystallization with reagents. It affords the usual reactions of oxide of zinc in a salified state, and is capable of forming numerous double salts with other bodies. Sulphate of zinc, in its crystallized form, is represented by the formula $ZnO, SO_3, 7\ HO$, and is composed of—

	Atomic weight.		Centesimally.
1 Eq. of oxide of zinc,	40·0	=	27·972
1 Eq. of sulphuric acid,	40·0	=	27·972
7 Eqs. of water,	63·0	=	45·056
	143·0		100·000

Uses.—This salt is used in medicine, in consequence of its physiological effects, which are, when administered in small doses, of an astringent, antisposmodic, and tonic nature; whilst taken in large quantities it is poisonous, causing vomiting, purging, coldness of the extremities, and a fluttering pulse. In full doses it acts as a safe emetic, but care should be taken that it be thrown off the stomach, for if retained for any length of time it occasions nausea and prolonged retching. In this capacity of emetic it is of great use where poisoning is suspected, as it acts rapidly. Sulphate of zinc is frequently used, owing to its astringent and caustic properties, in diseases of the eyes, and generally with good effect. In some cases it is used by dyers as a mordant; also as an *oil drier* for painting.

Carbonate of Zinc.—The preparation of the neutral carbonate of oxide of zinc is somewhat difficult, owing to the feeble affinity of the oxide for carbonic acid. If, however, the precipitate which occurs on adding a solution of bicarbonate of soda or of potassa to a solution of zinc be, after washing, disseminated in water, and carbonic acid charged into the liquor, the precipitate is dissolved in the form of a bicarbonate, and on evaporating the liquid in an atmosphere of carbonic acid, the neutral or monocarbonate of oxide of zinc is obtained. Its formula is ZnO, CO_2.

The ordinary carbonate of this oxide is a basic compound, containing five equivalents of base to two of acid. It is obtained by adding a solution of carbonate of soda to one of sulphate of zinc, taking care that the latter is in slight excess. The change which succeeds may be exemplified thus—

$$5\,(ZnO, SO_3) + 5\,(NaO, CO_2) = 3\,ZnO,\ 2\,(ZnO, CO_2) + 5\,NaO\ SO_3 + 3\,CO_2.$$

When the precipitant is in excess, a portion of it combines with the basic salt and cannot be removed by washing. For this reason carbonate of ammonia is sometimes preferred, only an equivalent quantity being employed, so that excess of the salt, which would dissolve a part of the zinc carbonate, is avoided. The precipitate in either case is washed well and dried at 212°.

Properties.—It is a loose white powder resembling the carbonate of magnesia of the shops, almost insoluble in water, easily soluble in acids with evolution of carbonic acid, and converted by a red heat into oxide of zinc. Like the oxide it is readily reduced by carbon at a red heat. **Moore** asserts that several of the varieties sold in the shops as calamine or carbonate of zinc contain no zinc whatever, but mixtures of carbonate of lime, sesquioxide of iron, and sulphate of baryta. When a sample of the zinc carbonate is suspected to be fictitious, its purity is readily ascertained by dissolving it in dilute hydrochloric acid, and adding an excess of carbonate of ammonia to the liquor. It should be wholly soluble in the acid, and the precipitate at first formed in the second case should be dissolved by the excess of the ammoniacal salt. A residue on the one hand, or a persistent precipitate on the other, indicates adulteration.

Uses.—Physiologically the carbonate of zinc has the same properties as the oxide, and is applied medicinally in like cases. In the arts, this compound has of late years, together with the oxide, acquired some importance as a substitute for white lead in painting.

Acetate of Zinc.—The reader will find this salt described in Vol. I. page 48. It may be stated here, however, that it can be conveniently prepared from the carbonate of this base and acetic acid. Two parts of the carbonate are heated with successive portions of acetic acid of specific gravity 1·045—containing sixty-four per cent. of water—till complete solution is effected. About five parts of acid are required. The solution is filtered while warm, and set aside to cool for a day or two, after which period it is decanted and concentrated to the crystallizing point, when, on cooling, the acetate will deposit. Acetate of zinc possesses a slight odor of acetic acid and a bitter saline nauseous taste. On being heated it fuses with the loss of water, and at length blackens, giving off the usual empyreumatic products resulting from the igneous decomposition of the acetates; and if the temperature be very elevated, the oxide of zinc will be likewise reduced.

Acetate of zinc is soluble in three parts of cold and in half a part of boiling water; in thirty parts of alcohol of eighty per cent. at the normal temperature, and in one part at the boiling point. The solutions have an acid reaction.

Uses.—Physiologically considered, the acetate of zinc is reputed to have the same properties as the sulphate, but some French writers deny that it has a poisonous effect even when administered in large doses. The salt is used by dyers as a mordant.

Zinc-white.—This pigment, to which considerable attention has been given of late years, is either the anhydrous oxide, the hydrate oxide, or hydrated basic carbonate of zinc. Its whiteness is equal to that of white lead, and not being tarnished like the latter by sulphurous vapors, it has been proposed to introduce it as a substitute for white lead in painting, especially as it affords a more permanent color, is cheaper, and does not involve the great risk and sacrifice of life which, however carefully the preparation of the carbonate of lead may be conducted, is occasioned among the workers engaged in that manufacture. The principal objection to its general adoption is, that the paint compounded with it is less drying than those in which lead constitutes the basis, and also that it does not cover or spread so perfectly as white lead; or, in the language of the painter, that it does not possess sufficient *body*. With regard to its non-drying qualities, improvements have been suggested which, if acted upon, would, in a great degree, obviate this objection; and as to the want of body, the painter can well afford to spread a thicker layer of the zinc-white, seeing that a given weight of the latter is considerably more bulky than the same quantity of the former, in consequence of the lesser density of zinc, as well as its much lower atomic weight, which is to that of lead in the proportion of thirty-two to one hundred and four.

Guyton de Morveau was the first to propose the substitution of oxide of zinc for the basic carbonate of lead in painting. **Lassaigne** likewise drew attention to the subject about 1821, and has lately communicated the fact that an oil painting finished at that time with oxide of zinc has hitherto retained its brilliant whiteness. The manufacture of the zinc-white owes much, however, to M. **Leclaire**, who was among the first to establish its manufacture on a large scale for this purpose. More recently several patents have been taken in England for the preparation of the oxide of zinc for the painter's use, and some of these will be referred to further on.

Fig. 645.

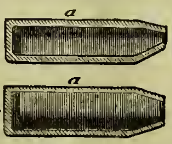
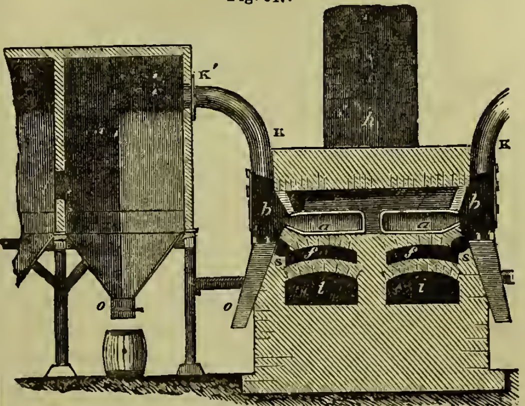


Fig. 646.

Fig. 647.



Manufacture.—At first metallic zinc was the material from which the zinc-white was prepared, the simple change effected being merely the dissipation of the metal in the form of vapor. While in this state, and still at a high degree of heat, the introduction of a current of air causes the metallic vapor to ignite, producing oxide of zinc in a finely-divided white powder, which, when collected, forms the substance in question. The arrangement by which this change is effected is shown in Figs. 645 to 646. In Figs. 645 and 646, the retorts from which the zinc is distilled are represented in section and elevation. They are similar to gas retorts, and are depressed cylinders, *a a*, of refractory clay, such as that of which glass pots are made. Their length is about twenty-eight inches, their breadth ten inches, and their height about six inches; the walls are two and a quarter inches in thickness; the aperture, *b*, which serves the double purpose of introducing the pigs of zinc, and allowing the metallic vapors to escape, is four inches in breadth and two in height. Eight or ten of these are placed in a double range, back to back, in a reverberatory, represented in plan and section in Figs. 648, 649, and 650. The fire is at C, the heat and flame of which pass over the cylinders and return beneath the floor of the reverberatory by the flue, C, *d*, *f*, *g*, *h*, into the chimney, as seen in Fig. 649. When the interior of the furnace and the retorts are observed at a reddish white heat, one or two bars of zinc are introduced into each of the retorts. The metal soon melts and enters into ebullition, the vapor being disengaged by the aperture, *b*, of each retort, where it comes into contact with a current of air heated in the cast-iron pipes, *s s*, to about 570° by the waste caloric of the furnace, and enters into combustion. The metallic oxide so produced is carried along by the current of gas into the pipes, K K, which surmount the mouth of the retort, and is deposited in the chambers, L L, four of which are in connection with each other by apertures alternately at the lower and upper part of their partition walls. The disposition of the condensing chambers and other parts of the apparatus is shown in Figs. 650 and 651. Here A indicates the furnace, B the pipes leading to the chambers, the last opening in the outer one of which is covered with a fine metallic gauze stretched on an iron sash or framework, for the purpose of intercepting all the particles of the zinc-white, whilst the meshes of the wire affords sufficient space for the egress of the nitrogen and other gases into the flue or passage, G G, leading to the chimney, H. In this conduit two other screens, similar to that above described, may be fixed, but somewhat finer, to prevent the loss of as little as possible of the powder. After a while the wire gauzes become covered with the powder, but before the meshes are closed they are cleaned and replaced.

Fig. 648.

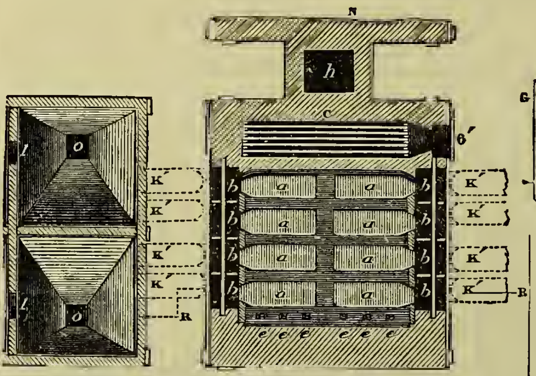


Fig. 649

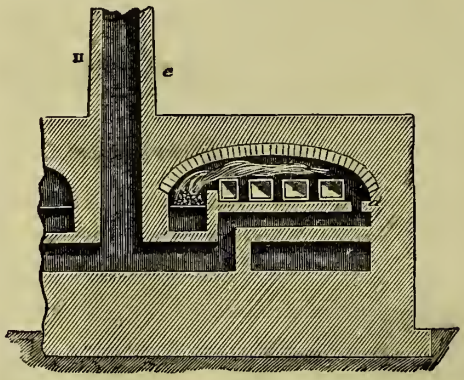


Fig. 650.

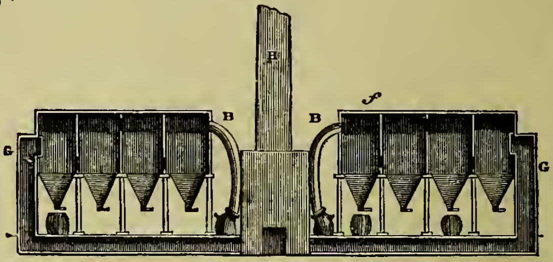
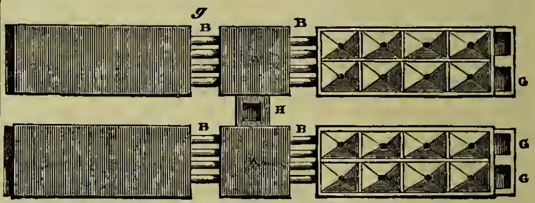


Fig. 651



The oxide of zinc thus produced is always of good quality, unless indeed an excess of impurities exists in the metal employed. That which is inferior is always deposited in the first chamber, being impregnated with the oxides of the metallic bodies contained in the zinc, and also with a finely-divided powder of the zinc itself, in consequence of some of its vapor being carried over before it underwent combustion. In consequence of these impregnations, the powder collected from the first chamber should always be screened, and the product devoted to the commoner kinds of painting. It is necessary during the formation of the oxide of zinc, to clear the openings communicating with adjacent chambers, lest the deposition of the powder on the walls should accumulate so as to block up the passage. This is done by means of an iron rod passed through the wall, and commanding the opening. After the conversion of the charge is completed, the oxide of zinc deposited in the chambers is removed simply by placing a barrel beneath the mouth of the hopper-shaped opening in the chamber, and drawing the sliding-plate which is used to secure it while working. The zinc-white is then easily scraped into the receiver, and there reduced by pressure to the least possible volume. It is now ready for the market, or for compounding with the oil as in the manufacture of paint. Three furnaces like those described, each furnished with eight retorts, work off from twenty-eight to thirty hundredweight of zinc in the twenty-four hours. This quantity ought to produce from thirty-five and a half to thirty-seven hundredweight and a half of zinc-white; but in practice the average yield amounts to only thirty-one and a half to thirty-four hundredweight.

Of late years several improved methods have been devised for the preparation of this substance, the most important of which, in the Editor's judgment, will now be briefly stated.

M. Leclaire's mode of operation is indicated in the following description and figures, taken and abridged from *Le Gènie Industriel.* Figs. 652, 653, and 654 show the distillatory furnace in longitudinal and transverse vertical sections and in plan. In these figures, A represents the fire-door, B the fire, and C the retorts, which are made of refractory material. Five are generally ranged at either side of the grate, but the number can be varied according to circumstances. The volatilized metallic vapors escape by the orifice, D, of the retort, before which are disposed a series of plates, E, called scrapers, attached to a horizontal iron rod, F, by similar pendant ones. By motion communicated by hand or machinery to the horizontal rod, the scrapers, E E, are moved backwards and forwards, and coming at each movement against the door of the retort, any oxide which adheres to the aperture is knocked off. The oxide and metallic vapors issuing from the retort are received in small receptacles, G G, which open into an inclined channel that terminates in another funnel-shaped conduit, G^1, and this leads them into the receiver, G^2. It is evident that the small conduits, G G, receive only such matters as solidify in the mouth of the retort, and which from their density cannot be drawn off to the receivers by the force of the current of gases passing through this arrangement to the chambers wherein the oxide of zinc is collected. A small plate-iron cage or box, H, is fixed over the mouth of each of the retorts in order to isolate them. It rests upon a framework of metal, H^1, fixed into the wall of the furnace, and so constructed that it may be removed at will by means of a crane, or by making it slide or roll on a framework or small railway. The anterior aperture is directed towards the orifice of the retort in such a manner that the products of the distillation empty themselves into it, and the posterior part has a door which may be opened at will. A trap-door, J, is contrived in the suspended plate, K, and which can be raised or lowered at will by an iron-wire rope passing through the posterior plate, I, of the box, H, without opening the door in this part of the latter. Sometimes, instead of lifting the trap-door, it is so formed that it can be drawn backwards when it is necessary to open it. K designates the suspended plate upon which the box or cage is placed; it is isolated in its construction from the chamber of oxidation. Currents of cold air may be directed upon this plate in order to cool it, so as to resist the temperature of the chamber. The hot air, admitted for the combustion of the metal, enters from the pipe, L; it communicates with the passage from the retorts to the receivers, and so drives the oxide of zinc formed into the latter. In the receivers the inventor places cloths for sifting or screening the products, the floor of each being a kind of hopper, or inclined plane, whereby the product gliding over the cloth is separated into its various qualities of fineness, and received at once into separate boxes placed beneath

Fig. 652.

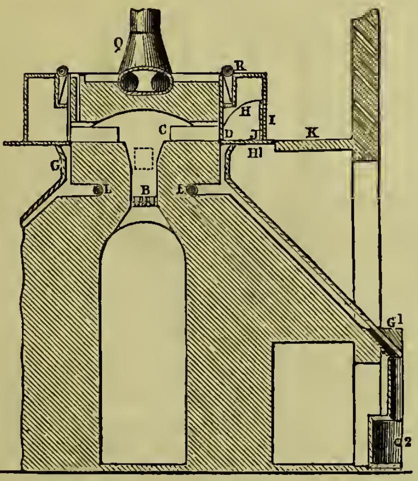


Fig. 653.

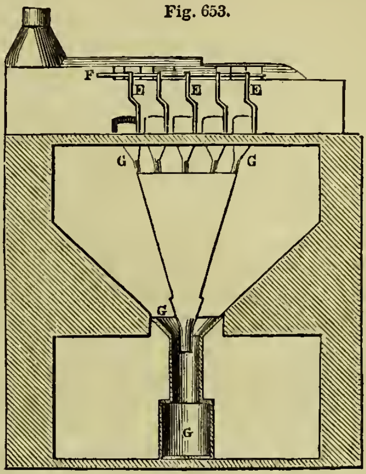
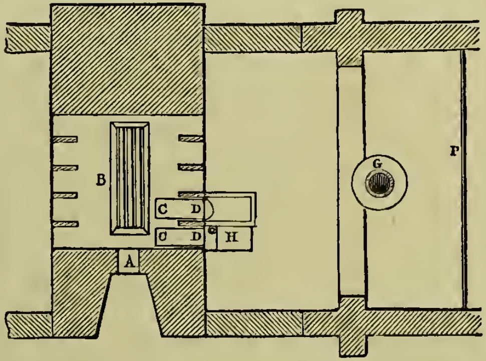


Fig. 654.



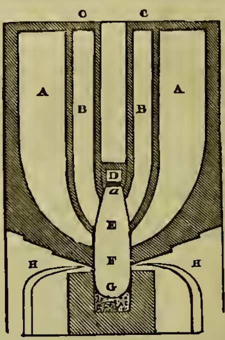
the sifter. In order to retain the finely-divided particles of zinc-white which arise from the agitation, cloths are suspended at regular distances. These, while they afford a passage to the gases, retain the particles of metallic oxide, and so prevent a loss of material.

A draught pipe, Q, draws off the air and gases as well as the finely-divided oxide from the oxidising chamber through the whole arrangement. Another pipe, R, placed at the top of each retort, draws into it by a funnel-shaped opening all vapors and powder emitted from the retorts whilst they are being charged, and the draught of which, whenever it is isolated from the oxidising chamber is sufficient to draw the products through a series of chambers not shown in the drawing, having cloth screens as usual to retain the oxide of zinc. The ventilation of both the draught pipes, Q and R, is effected by means of the waste heat of the furnace.

The same inventor combines the principle of the reverberatory furnace in the distillation of zinc for the purpose of making zinc-white. In this arrangement he so disposes the retorts that the flame from the coal fire circulates round them, and then passes into a chamber over the dome inclosing the retort, where pipes may be laid for raising the temperature of the air which is forced into the space surrounding the mouths of the retorts to oxidise the zinc vapors. The oxide so produced is conducted to receiving chambers in a manner somewhat similar to the two methods already described.

Rochaz's patent, dated in 1849, describes a construction of furnace suited either to the conversion of metallic zinc, or of ores of this metal, into the oxide. In the first case he uses clay crucibles, and arranges them in three rows in a furnace, supporting them by two intermediate fire-brick walls and by the side walls of the furnace, and so securing the crucibles at the surface that no vapors or smoke from the fire can issue from the chamber beneath them, but must pass off through passages in the bearing walls by small flues into the chimney. A loose slab or clay tile is used as a cover for the vessel wherein the distillation is effected, and the whole is inclosed by a flat roofing of refractory tiles, well cemented and raised a few inches above the crucibles, for the introduction of air from without, for oxidising the metallic vapors. This space leads to a large chamber, in which plates of iron are suspended in a slanting direction, so as to cause the current of vapor, loaded with oxide of zinc, to take a sinuous and zigzag course in passing through it. In addition to these he fixes bands of hemp, or other textile material, at intervals transversely in the chamber, with the view of intercepting the last portions of the zinc-white. Further he contrives that the upper end of these bands shall pass through the walls of the chamber and dip into a trough of water, so as more effectually to condense the zincous vapors in the interior. He directs that the chambers more distant from the furnace be constructed of sailcloth, which affords the advantages of being easily accommodated to space, and of keeping the walls cooled by means of a copious sprinkling of water, applied exteriorly, and which causes the oxide of zinc to deposit more readily. The same patentee claims a method for preparing the oxides from the ores by a previous roasting, and introducing them, thus prepared, with charcoal or slack, into cylindrical or square clay crucibles, somewhat similar to those employed for the reduction of the metal at Vieille Montagne, but without the condensers, opening into a closed channel in the front, through which a current of air is introduced, and which carries the oxide of zinc, resulting from the combustion of the metal, into a chamber disposed similarly to that described; likewise a blast furnace, represented in Fig. 655, for the same purpose. In this figure the mixture of roasted ore and fuel is introduced into the passages, A A, B B; others are filled with coke or other fuel; all of which are covered with tiles, C C; E, the cavity of the furnace, which is always kept filled with fuel from the passages, B, B, and in which the reduction of the ore is effected by means of the blast introduced through the tuyere pipes, H, H, more especially in the region of F. The slags and residue descend into the cavity, G, whilst the vapors of zinc pass off by the channel or flue, D, into the condensing chamber, as soon as the stopper, *a*, inclosing the mouth of the chamber, E, is removed. In the latter flue they meet a stream of air that effects their oxidation. The chamber is evidently required to be more extensive in this instance, owing to the gaseous products of the combustion of the fuel being carried along with the oxide of zinc produced in the flue, D; but, excepting this inconvenience, the patentee asserts that no other will result, for all the carbonaceous or sooty products, produced in the region of the blast, are entirely reduced or consumed in passing through the column of incandescent fuel above F, so that only pure gases, which are not calculated to discolor the product, are evolved.

Fig. 655.



Knowlys secured a patent in 1850, in which, among other claims, is a method of preparing the zinc-white from its ores, by dissolving the oxide in sulphuric acid, and, after clarifying the solution by filtration or subsidence, precipitating the metallic oxide with a solution of carbonate of soda. The precipitate, after being washed and collected, is then dried by means of heat and pressure, and the compound so produced is either used in this state or reduced by ignition to the oxide and then compounded into paint in the ordinary way.

Protheroe employs an ordinary cylindrical retort, having inlets for the passage of a current of air at the posterior end, and another for raking out the heavy oxide which forms on the surface of the metal and the walls of the retort, the lighter and finer particles being conveyed by a pipe with the current of air to a condensing chamber, which is divided by partition walls of brick, or other material, into several compartments. In each division he disposes two frames or sashes, on which fine wire gauze is stretched for the purpose of intercepting the particles of powder in their course through the several divisions. Metallic zinc is preferred as the substance to operate upon, and a reverberatory furnace is employed to reduce the metal to vapor. The quantity of heavy oxide skimmed off the surface of the metal and from the walls of the retort, is drawn out by a rake into a passage which conducts it to a receiver in an inclosed chamber beneath the level of the sole of the furnace.

In the method patented by Scott, a clay retort of the usual form is used, imbedded in sand, potsherds, or pumicestone, and so placed in the furnace that the products of the combustion pass freely round it. The metallic zinc, which is directed to be used, is introduced through an inclined aperture, which is usually closed by the unmelted portion of the block of zinc. The air which oxidises the vapors of zinc issuing at the top of the retort, is admitted to an intermediate chamber, where both meet, and the product is carried by the current through a passage into a depositing chamber, the roof of which is constructed of zinced iron, and is capable of being converted by a raised ledge, into a shallow cistern, for the purpose of cooling the interior. The bottom of the chamber is divided into a number of funnel mouths, which, by attaching cloth or other material to the narrow part, lead the zinc-white at once into casks placed beneath to receive it.

Geyelin's patent, sealed in 1853, is based upon the same principles, only the apparatus is slightly modified, and a jet of steam is employed to effect the rapid oxidation of the metallic vapors as they rise from the retort, and also to aid in producing a certain amount of caloric expended in the operation. The jet of steam is introduced at the farther end of the retort, and passing over the metal, it is decomposed, the oxygen combining with the zinc, and the hydrogen passing off to be consumed in the air channel outside the distillatory apparatus.

Titterton prepares the zinc-white from the dross and dregs of the purifying pots of the zinc-smelting establishments by heating them alone, or mixed with a certain quantity of coke or charcoal, according to their composition. He employs two condensing chambers, the first intended for retaining oxide of cadmium, or other impurities, and the second for collecting the light white oxide of zinc. This patentee employs pressure, and a subsequent heating process, with the view of obtaining a denser compound, and therefore better suited for painting.

Zinc-white Paint.—Like white lead, the oxide of zinc requires to be mixed with an oily vehicle, to be applied in painting. As oxide of zinc does not readily form a saponaceous compound with fats or oils like oxide of lead; the paint which is prepared with it and ordinary linseed oil, does not dry or harden for a long time. This peculiarity was at first one of the principal drawbacks to the more general use of the zinc instead of the lead paint. Another of its defects is said to be its transparency, owing to which a layer of the zinc-white paint does not exhibit so much *body* or opacity as a similar one of white lead. Both these defects, which can be almost entirely overcome, are more than compensated by the permanency of the oxide of zinc as a pigment under all circumstances, and its comparative innocuousness both in the manufacture and the application; whereas the poisonous qualities of white lead constitute a fundamental objection to it. At first, manufacturers of zinc paint were led to the adoption of the practice of boiling the oil with a large quantity of litharge, for the purpose of causing it to be more siccative; but by this method the color of the paint is rendered liable to tarnish on exposure to sulphurous emanations. Instead of litharge, experiments have led to the choice of salts of zinc, such as the chloride and sulphate, a small per centage of which, on being mixed with the oil or oxide, confers upon the paint the property of readily hardening. The same result is obtained by employing an oil dried by boiling it with about five per cent. of peroxide of manganese, or even magnesia has been recommended, and is said to answer quite as well as the manganese; in either case a paint retaining its white color permanently is obtained.

Manufacturers classify the several qualities of the zinc-white into four kinds, namely, *snow white*, *zinc white*, *stone grey*, and *grey oxide;* the first two are employed where a pure unalterable white color is required; the third is used for a ground color for the walls of houses, iron painting, and the like; and the fourth is peculiarly adapted for the painting of ships and wood-work, and likewise for the ground of more expensive colors on stone or cement. Various shades may be given to paint of which zinc-white constitutes the basis, by grinding up with the oil, used as the vehicle, several metallic and other compounds of an unalterable nature in different proportions. Thus, an orange-yellow is obtained by using kermes—sulphide of antimony; a citron-yellow by employing chromate of zinc; a green by adding a mixture of chromate of zinc and a few per cents. of cobalt blue. In like manner oxides of iron and of manganese, ultramarine, lampblack, *et cetera,* communicate tints to the paint; all of which, owing to the absence of lead, are unaltered by atmospheric influences, sulphide of hydrogen, or other emanations.

Sometimes a very permanent and useful paint is prepared from the natural ores of zinc without subjecting them to any of the manufacturing processes already referred to for preparing the oxide of this metal. This is the case with the zinc-stone of Virginia in the United States, which has an average composition of—

Oxide of zinc,	25·00
Carbonate of magnesia,	11·21
Alumina,	17·00
Silica,	28·00

This mineral constitutes a solid rock on the surface of the ground, and when pulverized and mixed with oil in proper proportions, forms on the surface to which it is applied a hard closely-adhering stone coating, impervious to water or fire. Its ordinary tint varies from a light drab to dark brown. This paint is capable of receiving a high polish.

Oxide of zinc, or zinc-white, besides its application in painting, is valuable for paper-staining, card-enamelling, the bleaching of lace, the glazing of pottery and porcelain ware; and the lighter white portions are used for producing the down on artificial feathers.

Analysis and Testing of Minerals and Compounds of Zinc.—A short summary of the method followed in the assaying of zinc ores has already been laid before the reader. It is almost needless to state that in consequence of the numerous sources of error almost inseparably connected with it, the process so described leads to no very accurate results. Hence in all cases where great precision is required, the liquid process must be adopted. Considerable difficulties are encountered in the analysis of zinc ores, and the compounds of this metal with others with which it is alloyed, in many valuable mixtures used in the arts—arising from the fact that sulphide of hydrogen does not separate members of the fifth and sixth group of bases, namely, mercury, silver, copper, cadmium, arsenic, *et cetera*, from zinc in acid solutions, as was for some time supposed; nor does potassa or ammonia, on the other hand, serve to isolate it from iron, nickel, and other members of the fourth group. These considerations have led to several processes for removing the cause of error, and conducting to more accurate determinations. As regards the action of sulphide of hydrogen, most of the analytical manuals to which the chemical student has access give details which are highly erroneous, and which, at best, serve only for qualitative rather than accurate quantitative determinations; for, in direct contradiction to what is commonly taught, sulphide of hydrogen does precipitate considerable portions of zinc in the form of sulphide from highly acid solutions. This fact was a few years ago very conclusively decided by Mr. C. CALVERT, whose research shows that the above agent cannot be employed in the manner detailed in the manuals to separate copper and other metals of its class from zinc. Again, potassa, which was for a long time supposed to be capable of parting zinc from iron, nickel, cobalt, and manganese, by dissolving the zinc in its excess, leaving the others permanently precipitated as sesqui- and protoxides, is now known to do so only partially; so that under almost every circumstance in which the precipitation is effected, more or less oxide of zinc is found in the separated oxides. Without going, therefore, into long details of the several processes recommended, the most trustworthy, and, at the same time, most expeditious method for the analysis of zinc ores and alloys will here be given.

The ore or alloy should be dissolved in nitric acid, and evaporated to dryness at a moderate heat, exercising the usual amount of care in the operation. If the subject be an alloy into which tin or antimony may have entered, these metals will be converted into insoluble binoxide in the case of tin, and into antimonious acid in case of antimony, particularly if the assay be treated with some fuming nitric acid, as it becomes nearly evaporated. After thorough desiccation the mass is treated with boiling water, filtered and washed; the binoxide of tin or antimonious acid dried, burned, and weighed with due precaution, and the filtrate with the washings containing copper, cadmium, or other substances with the zinc, as the case may be, treated further. According to FLAJOLOT, the best process is to slightly acidify with hydrochloric acid, and boil the solution, and add hyposulphite of soda in excess to it whilst hot; sulphides of copper, cadmium, *et cetera*, are precipitated entirely free from zinc, by the decomposition of the hyposulphite. After thorough washing, the precipitated sulphides may be dissolved in acid, and the quantity of copper is determined by the processes already detailed under *Copper;* or if cadmium be present the solution may be treated with carbonate of ammonia in excess, and the vessel left exposed for some time, when carbonate of cadmium falls to the bottom, and the copper remains in the solution, to which it gives a deep violet or blue color. After the carbonate of cadmium is filtered off, washed with a solution of carbonate of ammonia and dried, it may be burned and weighed as oxide. The copper may be estimated with a standard solution of cyanide, or of monosulphide of potassium in the usual volumetric way. The zinc, iron, and nickel, with other matters capable of being separated by the reagent, may be thrown down from the solution with protosulphide of ammonium, the precipitate collected, washed, and dried at 212° till it ceases to lose weight; its entire weight is then noted, and the chief part introduced into a German glass tube on a platinum mattress or boat, where it may be heated to redness, whilst a current of sulphide of hydrogen is passed through the apparatus. When the heat has been sustained for a quarter of an hour, the lamp is removed, but the current of gas is still maintained till the tube and its contents are cooled. The platinum boat is then removed, and its contents emptied into a beaker, and treated with dilute hydrochloric acid, containing one part of strong acid in ten or twelve parts of water; sulphide of zinc is dissolved while the sulphides of cobalt, nickel, and iron remain intact. The quantity of the latter may be determined according to the processes which have been given respectively under *Cobalt*, *Iron*, and *Nickel*, and the zinc in the solution may be estimated by bringing the liquid to a boiling heat, and adding sparingly a solution of carbonate of soda, as long as a precipitate is formed, boiling the menstruum for some time to expel all carbonic acid, and then collecting the basic carbonate of zinc on a filter, washing with hot water, drying, igniting, and weighing the residue. During the ignition all the carbonic acid is expelled from the basic carbonate, so that only oxide of zinc remains, from the weight of which that of the metal may be calculated, since 40·0 parts of it contain 32·0 of zinc.

The oxide of zinc contained in ores of this metal may be determined by heating a weighed portion of them, finely ground, to redness for some time, and then treating the powder with a solution of carbonate of ammonia as long as anything is dissolved; the filtered liquid is next evaporated to dryness, and the residue heated to redness and weighed; this weight indicates the amount of oxide of zinc existing as oxide or carbonate in the ore. SCHWARZ, instead of evaporating the ammoniacal solution of zinc, as in the foregoing, precipitates the metal as sulphide, either by passing sulphide of hydrogen through the liquid, or adding sulphide of ammonium to it. The sulphide of zinc is collected and washed with water, mixed with a little ammonia, and then introduced with the filter into a wide-mouthed flask, where it is treated with an acid solution of sesquichloride of iron, and slightly heated. Decomposition of the sulphide of zinc takes place in this case, and a reduction of a proportionate quantity of the iron salt to the state of protosalt, as explained by the formula—

$$\text{ZnS} + \text{Fe}_2\ \text{Cl}_3 = 2\ \text{Fe Cl} + \text{Zn Cl} + \text{S}\,;$$

that is, for every equivalent of sulphide of zinc one of the sesquichloride of iron is reduced to the state of protochloride, while sulphur is separated from the former, and chlorine from the iron salt assimilated. The liquid, as soon as it becomes clear by the deposition of the sulphur, is filtered off, and the quantity of iron in the state of protoxide estimated volumetrically by means of standard solutions of permanganate or of bichromate of potassa, and the amount of zinc deduced therefrom, since 56 parts of iron will represent 32·0 of zinc.

In the analysis of brasses, Pelouze's volumetrical method may likewise be resorted to; and, according to Calvert, with perfect accuracy. The brass is treated with an acid till perfect solution takes place, ammonia is added in excess, and a standard solution of monosulphide of potassium introduced from a burette, whilst a black precipitate forms in the liquid, and until a white one begins to appear. The quantity of copper being found from the volume of liquid used in the precipitation, that of the zinc may be taken as the difference.

Zinc is separated from nickel in many ways. If the alloy containing the two metals be dissolved in sulphuric acid, and the sulphates so produced be treated with acetate of baryta, a sulphate of baryta, with the corresponding acetates of nickel and zinc, will be produced, with a little free acetic acid in proportion to the quantity of uncombined sulphuric acid which existed in the solution. Sulphide of hydrogen passed through this mixture, throws down the zinc as sulphide, leaving the nickel in solution. The precipitated sulphide of zinc and sulphate of baryta are filtered and washed, then treated with dilute nitric acid to dissolve the sulphide of zinc, and after removing this by filtration and washing from the insoluble baryta compound, the oxide is thrown down as a basic carbonate by treatment with a solution of carbonate of soda at a boiling temperature, then filtered, washed, and estimated as oxide, in the manner already detailed. The nickel can be thrown down as oxide, after expelling the sulphide of hydrogen with caustic soda or potassa, and its weight estimated in the usual way. Wöhler separates the two metals by adding an excess of potassa to the solution containing them, then a sufficient quantity of hydrocyanic acid to dissolve the precipitate so formed. Double cyanides of the metals with potassium are thus produced, and which behave differently with protosulphide of potassium, the zinc salt only being decomposed by this reagent. By treating the solution, therefore, with protosulphide of potassium, sulphide of zinc separates completely, and may be removed and estimated in the usual way. The filtrate and washings should be evaporated to dryness with strong nitric acid to destroy the cyanogen compound, and the nickel determined by precipitating it with potassa or soda as already indicated.

Statistics.—Zinc was not an article of commerce previous to 1822, when it was imported in moderately large quantities, but only to be exported for the most part to India. The applications of the metal in the industry of the nation became gradually extended, till at present the home consumption averages about twenty thousand tons annually. The following table exhibits the imports and exports of the metal from 1823 to 1851; since that period the home consumption has been greatly on the increase, whilst the export remains about the same:—

Years.	Imports.	Exports to India.	Total Exports.	Home used.	Stock in January.	Highest and lowest prices
1823	5400	4536	4700	—	970	£22 to £23.
1824	9199	7185	8068	24	1140	£24 to £23.
1825	5556	4835	6112	171	413	£22 10s. to £41 10s.
1826	4839	7374	8330	22	924	£28 to £15 10s.
1827	5999	5535	6929	290	1262	£16 10s. to £14.
1828	4566	4806	4943	536	2447	£14 10s. to £11 10s.
1829	4230	3505	3964	684	2012	£12 to £9 7s. 6d.
1830	4422	3385	3479	843	1750	£9 10s. to £11.
1831	3821	2896	3134	941	1512	£11 5s. to £9 5s.
1832	3140	2044	2995	1093	1490	£10 10s. to £11.
1833	2800	1225	1883	1355	1020	£10 10s. to £12.
1834	2100	882	1419	1756	710	£12 to £14 10s.
1835	6500	2497	3943	2205	1350	£15 to £17.
1836	8600	1490	6269	2184	3110	£16 10s., £23 10s., and £19 10s.
1837	4380	1811	3200	2335	2750	£18 10s., £12, and £15.
1838	6265	528	1858	3596	2553	£15 10s. to £20.
1839	8910	1538	3391	4560	3650	£18 5s. to £21 15s.
1840	4965	2637	4091	4181	1536	£20 to £23 10s.
1841	6509	990	1406	3665	2111	£23 10s. to £40.
1842	5500	1584	1900	2641	2800	£36 to £24.
1843	10,173	3459	6445	4125	3750	£23 to £22.
1844	10,393	5826	5925	5388	4021	£22 5s. to £22 10s.
1845	12,903	2969	3084	7459	3296	£22 5s. to £22 15s.
1846	11,434	4875	4967	8450	6800	£22 to £19 10s.
1847	12,729	3301	3631	11,794	2250	£22 to £19 10s.
1848	13,525	2831	3773	9344	2000	£19 15s., £13, and £15.
1849	15,915	3927	5397	8726	2020	£15 to £16 5s.
1850	18,626	3121	4537	11,262	4000	£16 10s., £17 10s., £15, £16 10s.
1851	—	—	—	—	6827	£16 5s. to £15, May 1.

The duty on imported zinc from 1823 to 1825 was twenty-eight pounds ten shillings per ton; this was reduced in 1826 to fourteen pounds; in 1827 to twelve; in 1828 to 1832 to ten, and in 1833 to 1842 to two pounds per ton. The duty levied in 1843 and 1844 was one shilling per ton, and since then all tax upon the imported metal was abolished. The average annual production from 1842 to 1848 was thirty-two thousand five hundred tons, of which—

Silesia made sixty-five per cent.,	or	21,000 tons.
Belgium made twenty "	or	6,500 tons.
Poland made eight "	or	4,000 tons.
Cracow made four "	or	
England made three "	or	1,000 tons.
Total,		32,500 tons.

The smelting of zinc declined in England from 1850 till within the last few years that it has been a little more spirited in the several localities mentioned in the commencement of this article; during the same period the Continental establishments, more especially those of Belgium, have greatly enlarged their production. The quantity of zinc produced in the latter country in 1858 was twenty-five thousand six hundred and seventy tons.

The following represents the quantity of zinc smelted in the Prussian States from 1837 to 1848, inclusive:—

1837,	21,546,600 lbs.	1843,	36,047,200 lbs.
1838,	20,983,200 lbs.	1844,	41,314,100 lbs.
1839,	21,636,600 lbs.	1845,	43,861,200 lbs.
1840,	20,879,800 lbs.	1846,	43,961,000 lbs.
1841,	19,977,900 lbs.	1847,	44,221,800 lbs.
1842,	27,612,600 lbs.	1848,	39,873,600 lbs.

Of this quantity there were produced in the upper district:—

	1846.	1848.
In Silesia,	35,538,200 lbs.	36,193,100 lbs.
In Westphalia,	189,900 lbs.	75,000 lbs.
In Rhenish Prussia,	5,322,900 lbs.	3,605,500 lbs.

In France the quantity entered annually for home consumption to about 1848, amounted to eighteen or twenty thousand tons. Estimating the present consumption of that country at thirty thousand tons, that of England at twenty thousand tons, the other Continental nations and America at twenty-five thousand tons, the gross production would appear to average at present from seventy to seventy-five thousand tons annually, a quantity which approximates to the present yield of the several smelting works in operation.

SUPPLEMENTARY MATTER,

BY

PROFESSOR HORSFORD OF AMERICA.

ACETIC ACID.—Insert at foot of column 1, page 3, Vol. I—The oxidation of the glycerin in fats also appears to be a source of acetic acid. By melting rancid Chinese vegetal tallow—palmitate and oleate of glycerin—in a flask, a strong smell of acetic acid is observed. **Redtenbacher** found that an aqueous solution of glycerin is decomposed by the presence of ferments, and yields acetic and metacetonic acids. By doubling the formula $C_6\ H_8\ O_6$ of glycerin, and substracting 4 H, one obtains $C_{12}\ H_{12}\ O_{12}$, that is, three equivalents of the hydrated acetic acid. The oxidation of H_4 by the oxygen of the air, would produce the same result. From this it follows, that the acid reaction of rancid fats and oils, is for the greater part produced by the presence of acetic acid formed by the slow combustion of glycerin.—H.

Insert at foot of column 1, page 16.—A very neat apparatus for making small quantities of vinegar from alcohol, constructed by Dr. **Spitaler**, has been used in Germany for several years. It consists of a cylinder of glass, ten inches high and eight inches wide, filled up with coarsely-powdered charcoal. A glass cover, with a moderate aperture for the admission of air, closes the top of the cylinder, while a small cock is adapted near the bottom for the removal of the fluid. The apparatus must be kept at a temperature between 63°—77°. Every evening six ounces of a mixture of one quart of alcohol, specific gravity 0·859, and eleven quarts water, are poured slowly and in a fine stream evenly over the charcoal, after which the cover is laid on. The following morning the corresponding quantity of vinegar may be drawn from the cock.—H.

Insert at foot of column 2, page 16.—It may here be interesting to mention an indirect mode of producing vinegar from wood. During the last few years, especially during the crisis caused by the ravages of the potato disease, serious experiments on a large scale have been instituted, with a view to substitute saw-dust and woody fibre in general for potatoes in the distillation of spirit. Many years ago, **Braconnot** found that saw-dust, cotton and flax fibres, *et cetera*, are converted into sugar by concentrated sulphuric acid. The sugar thus obtained is fermented in the usual manner, and the alcohol generated may be easily converted into acetic acid by any of the processes mentioned in the text. The cheapness of sulphuric acid, and the universal command of woody fibre, open a promising future to the new and ingenious process.—H.

Insert after Pyroxylic Spirit or Wood Naphtha, page 25, column 2.—It may be well to remind the American readers, that the high duty on alcohol in England, renders the extraction of the pyroxylic spirit from wood a matter of great importance to the chemist. It is usual in England to burn wood spirit in lamps, and to use it generally as a substitute for alcohol, whenever its empyreumatic flavor is not objectionable, as tolerably pure wood spirit can be obtained cheaper than alcohol.

At page 27, middle of column 2, the reader is directed to use either *sulphuric* or *hydrochloric* acid for the purification of wood vinegar. It is far preferable to use hydrochloric acid for decomposing the lime-salt. Sulphuric acid forms with the lime gypsum, which converts the fluid to be distilled into a paste which it is very unpleasant to distil, as it boils irregularly and sometimes with explosions.—H.

The chloride of barium vinegar-test, mentioned at page 34, column 2, may perhaps be objected to, as calculated to mislead those unacquainted with chemical manipulations. In view of this, **Böttger** has recommended a concentrated solution of chloride of calcium, for detecting the adulteration of acetic acid by sulphuric acid. He found that all kinds of vinegars, whether prepared from wine, alcohol, fruit, or beer, notwithstanding the small amount of sulphates which they contain, are perfectly indifferent to a concentrated solution of chloride of calcium. By adding to two drachms of vinegar a piece of crystallized chloride of calcium of the size of a small nut, and heating the whole to the boiling point, a precipitate of gypsum will fall down on cooling, if the *liquor contains only one-thousandth part of sulphuric acid.*—H.

In connection with the mordant made by decomposing alum by acetate of lead—see page 37, column 1—it may be stated that the preparation of acetate of alumina by double decomposition of sugar of lead and sulphate of alumina, gives rise to immense quantities of sulphate of lead, which is in many localities treated as a worthless refuse. By digesting it with a strong solution of carbonate of soda, it is converted into an inferior kind of white lead, which might be profitably disposed of, or else dissolved in acids for the preparation of lead salts.—H.

At page 41, foot of column 2, it is stated that the vinegar sold contains a small quantity of acetic ether, with the view, no doubt, of improving its taste and odor. It may be added, however, that an interesting formation of this compound was observed in a sour and decomposed sugar-cane which had been sent from Andalusia to Paris. On splitting the cane open, a very strong smell of acetic acid and acetate of oxide of ethyle was perceptible. It is obvious that the presence of this compound, under the given circumstances, must be explained by the contemporaneous formation of acetic acid and alcohol from the sugar, both of which combine in the nascent state to form acetic ether.—H.

At page 42, column 1, it is stated that for commercial purposes, the protoacetate of iron is manufactured by introducing the materials into a large cast-iron boiler. By employing a copper kettle or boiler, the solution of the iron is effected more rapidly by galvanic action. As long as there is any iron left undissolved in the kettle, the copper will not be acted upon by the acid. A few drops of a solution of bichloride of platinum, added to six or eight ounces of concentrated hydrochloric acid used for dissolving tin, will induce a very violent action, and the tin will dissolve, requiring but little aid by heat. The same takes place when bichloride of platinum is added to the acetic acid for preparing protoacetate of iron.—H.

Insert, in connection with white acetate of lead, page 44, column 1.—It is a well-known fact among phytochemists, that sulphide of lead has a great affinity for coloring matters. Based on this observation, a German chemist proposed to decolor a colored solution of acetate of lead, by the addition of a small quantity of sulphide of potassium or sulphide of calcium. After boiling and filtering, the menstruum is clear and without hue.

ALCOHOL.—At page 50, top of column 1, it is stated that alcohol is never produced except by the vinous or alcoholic fermentation of particular substances. There is one exception to this rule. Pure olefiant gas is absorbed by agitation with concentrated sulphuric acid, with formation of sulphovinic acid; and by diluting the latter compound with water, and distilling the fluid, alcohol is obtained. This fact was discovered twenty-seven years ago by HENRY FLENNEL, though, singular to say, the discovery has lately been claimed by BERTHELOT.—H.

Insert at foot of column 1, page 107.—*Dunder* fulfils two important offices in the distillation of rum. In the first place, the large quantity of acetic acid contained in it, and formed at the expense of alcohol during fermentation of the wash, serves to decompose the sugarate of lime, contained in the generality of West India molasses in considerable quantities. It is for this reason that dunder increases the yield of rum. Sugarate of lime does not ferment, and when present in considerable quantity, actually opposes the fermentation of the wash; so that without dunder, fermentation would proceed so sluggishly that most of the alcohol would be converted into vinegar. This occurrence might be avoided by adding the diluted molasses containing sugarate of lime, to its own bulk of strongly fermenting wash. The carbonic acid of the fermenting liquor would then perform the office of the acetic acid of the dunder, by precipitating the lime as carbonate of lime and liberating the sugar. The American Editor disproved the idea that dunder is connected with the fine flavor of rum, by two experiments. In one trial, molasses—from which all the lime was precipitated by sulphurous acid—and water only were used. The resulting rum was a very fine-flavored spirit, and the yield was perceptibly greater than from molasses not thus treated, though from similar cane. Another trial was made by partially filling the rectifying vessels or retorts, as they are called in Jamaica—they are like the wash-heater, as prepared B, Fig 78, and connected with the still in the same manner—with dunder, with a view to increase the flavor of the rum, as might be expected if the flavor proceeded from that source. The rum, however, thus obtained had the disagreeable flavor of the dunder totally different from that of *Old Jamaica.* The flavor of the rum appears to depend entirely on the presence of a fusel-oil, the formation of which is immediately dependent on the proportion of the surface of the wash exposed to the air during fermentation, to its entire volume. It is well known that two contiguous sugar plantations will produce very different qualities of rum, though operating in the same identical way. But it has been observed that in such cases the size and the exposed surface of their fermenting vats were different, or if not, the stills were of different capacity. The protracted boiling of the wash in very large and deep stills, injures the flavor by increasing the empyreumatic products. From the above observation it would follow, that the origin of the genuine flavor is intimately connected with the more or less complete oxidation of the molasses ferment induced by the greater or smaller surface of the wash—compared with the bulk—exposed to the air. Large cubical cisterns, holding one thousand and more gallons, yield an inferior rum, as compared with smaller vats having a larger exposed surface. Similar observations made by LIEBIG with regard to Rhenish wine appear to confirm this opinion.

The second office fulfilled by dunder—an office of some importance for the more rapid development of fermentation—is by its richness in ferment The colonial distiller does not employ any yeast for inducing fermentation of his wash; he is consequently obliged to work upon more dilute solutions of molasses and skimmings—collectively called *sweets*—than are used by his continental competitors. Any, even the slightest source of ferment, must therefore be welcome for his purpose. Dunder is such a source. Ferments, it is well known, are destroyed by boiling-heat of water, and recent dunder is in that respect perfectly inert; but by exposure to air in shallow tanks, an oxidation and regeneration of the *killed* ferment takes place, and it is to this circumstance that a part of the favorable action of dunder must be ascribed.

Without the assistance of dunder a more rapid fermentation of the wash may be obtained by converting the cane-sugar contained in molasses into grape-sugar, by treatment with a small quantity of acid, which is subsequently neutralized. It has been stated that less ferment is required for converting grape-sugar into alcohol than cane-sugar, a fact which will render it less miraculous to hear that some plantations manufacture a superior rum while their sugar is nearly as dark as coal-tar. Molasses from such sugar contain chiefly grape-sugar. Allusion has already been made to the fine flavor of rum made from molasses which were obtained by boiling sugar with an excess of bisulphite of lime.

Cleanliness in the operation of the distilling is a standard admonition of the theoretical world, woefully disregarded by the practical. In fact, it appears that a premium is offered to malpractice in this instance, as many of the most detestable colonial distilleries turn out very creditable produce. Whether the exception proves the rule in this case, must be left undecided. However, if cleanliness is not absolutely required for improving the flavor of the spirit, it would be a charity to the still-house bookkeeper, who is condemned to pass part of his lifetime in these disgusting dungeons.—H.

Page 117, column 2, *Alcoholometry.*—To the analytical chemist it happens sometimes that only small quantities of the alcoholic fluids are at his command. In such cases it is almost impossible to obtain a correct result, by determining the specific gravity of the few drops of alcohol obtained by distillation. It is safer to subject the alcohol obtained to an organic analysis by combustion with oxide of copper, and calculate the quantity of absolute alcohol from the resulting carbonic acid and water. This is of course only applicable when the alcohol does not contain other volatile bodies, like ethereal oils, *et cetera.*

ARSENIC.—At the top of column 2, page 215, Vol. I., insert—In the presence of oxide of iron, minute quantities of arsenic cannot be detected by the blowpipe. In that case, the oxide of iron must be treated with a boiling solution of potash, which is afterwards neutralized by sulphuric acid, and tested in MARSH'S apparatus.

In same page and column the reader is directed to drop a few fragments of pure zinc into MARSH'S tube-apparatus. It deserves to be remarked, however, that pure zinc, especially when in large pieces, frequently dissolves so slowly in dilute sulphuric acid, that it is impossible to obtain a steady hydrogen flame. The addition of a drop of bichloride of platinum, or of a small quantity of platinum black, will remedy this difficulty. If the fluid to be tested contains any considerable quantity of arsenic acid, this alone is sufficient to produce a violent reaction of the acid on the zinc.—H.

BALSAM.—Vol. I., column 1, page 223.—*Canada Balsam.*—This balsam is mostly used by optical instrument-makers for cementing together the different parts of achromatic lenses, NICHOL'S prisms, *et cetera.* It may be here added that Japan varnish is a balsam derived from *Rhus vernix*, and serves to impart a brilliant lustre to metallic and other objects, hence denominated *japanned articles.*

BEER.—In connection with the analysis of beer, pages 281–284, the following may be given:—

ANALYSIS OF VARIOUS KINDS OF CELEBRATED BEER.

	Water in 100.	Extractive matter.	Alcohol.	Carbonic acid.	Analyst.
Barclay's ale,....	86·93	6·02	6·90	0·15	Raiser.
Burton ale,......	79·62	14·50	5·88	0·04	Hoffmann.
Pale ale,........	89·85	4·50	5·65	0·07	"
Barclay's porter,	88·74	5·98	6·10	0·18	Raiser.
London porter, ..	86·28	6·80	6·91	—	Balling.
Bavarian ale,....	90·95	4·70	4·34	—	"
London ale,......	76·03	15·88	8·08	—	"

BENZOL.—Insert at foot of column 1, page 286, Vol. I.—The rectified volatile oil from coal-tar, distilling between 212°–320°, and consisting mostly of benzol, toluol, and cumol, has been strongly recommended for oil paint in the place of oil of turpentine. It has the advantage of evaporating rapidly, whereby apartments painted with oil paint are rendered much sooner inhabitable.

A curious and interesting application has been made of benzol by the well-known photographist, M. DE ST. VICTOR, based upon the property of this fluid, to be lighter than water and insoluble in it, and to be kindled with the greatest facility by a small flame in contact with air even at low temperatures. He found that benzol, to which have been added a few pieces of potassium or phosphide of calcium, readily inflames when thrown on water. An experiment was made on the Seine in Paris, in which three hundred grammes of benzol were inclosed in a glass-bottle, with half a gramme of potassium. The bottle was floated down the river, and suddenly broken. The potassium ignited and set fire to the benzol which burned with an immense flame, which, though smoky, had great intensity, and lasted fully a minute in spite of a strong breeze.

A repetition of this experiment in the fountain of the garden of the Palais Royal gave the same result. In spite of a heavy rain, the flame lasted over a minute.

M. DE ST. VICTOR proposes a mixture of benzol with sulphide of carbon in which phosphorus has been dissolved, as a close imitation of the famous liquid Greek fire.—H.

BISMUTH.—Insert at foot of column 1, page 288.—An alloy for galvanoplastic moulds is prepared by fusing together eight parts of bismuth, eight parts lead, three parts tin. This mixture melts at 225°. For preparing the mould, the alloy is fused and poured into a paste-board boat of about one quarter inch depth; it is then stirred with a heated iron-wire until its surface is perfectly even and bright. As soon as it has acquired a pasty consistence, the medal to be moulded is slightly heated, and immediately pressed on the alloy, and kept under pressure until cool.—*Böttger.*

BLEACHING.—Insert at foot of column 1, page 315, Vol. I.—Mr. L. BENNER, chemist of KÖCHLIN'S print-works at Darnetal, near Rouen, has lately recommended the use of sugarate of lime—sugar-lime—in place of caustic lime for bleaching of cotton fabrics. He describes his process as follows:—For one scouring operation, two hundred pieces of fourteen pounds each are worked upon, and the operation is performed in large kiers, heated on the open fire, and under a pressure of about twenty-two pounds to the inch. As soon as the pieces are singed, they are passed through a washing-machine—similar in principle to ROBINSON'S—in order to moisten them sufficiently to prevent any danger of combustion. After this they are wound by a mechanism into a tub in which they are spread in large folds. During the latter operation a milk of lime, containing forty pounds burnt lime, runs on the pieces in such proportion that the forty pounds of lime will be used up by the two hundred pieces. From this liming tub the pieces are mechanically transferred to the bucking kier, in which they are arranged in separate layers. After covering and fixing the fabrics by wooden cross-bars, as much water is added as will cover the pieces to the height of twelve inches, after which the sugar-lime is added. The latter is prepared by mixing in a tub thirty pounds burnt lime with seventy-two pounds boiling water; after slaking, thirty-six pounds more of hot water are added to dilute the lime-paste. To this milk of lime are added fifteen pounds of molasses, previously diluted with thirty-six pounds of hot water. The whole is well stirred and thrown into the bucking kier, whereupon the cover is fastened, and the charge kept boiling for eight hours. The fire must, however, be increased very gradually, so that the operation is finished in about ten hours.

This operation ended, the pieces are taken out, passed twice through the washing-machine, and brought back again into the bucking kier. The pieces are folded up as before, covered with twelve inches of water, which is mixed with the sugar-lime prepared from thirty pounds of burnt lime and ten pounds of molasses. The charge is again boiled during eight hours; the pieces are then removed, passed twice through the washing-machine, and steeped in hydrochloric acid of specific gravity 1·010 = 2° Twaddell during four hours. They then undergo two washings—are brought back to the bucking kier a third time to be finished for bleaching by a single soda-ley.

The sugar-lime being readily soluble in water, and acting in all respects like free lime, has, of course, the great advantage of intimate contact with all the particles of grease and resinous substances which are fixed on the fibre; while the caustic lime, in consequence of its restricted solubility, especially in boiling water, is less complete in its saponifying functions.

The bleaching process is carried out as follows:—After packing the pieces in the bucking kier, and covering them with twelve inches of water, a solution of sixty pounds of soda-crystals is added, the cover of the kier fastened, and the charge boiled for three hours. The fire is then withdrawn, the steam allowed to escape, and the cover removed. The soda liquor is drawn off and replaced by cold water, to which a resin-soap, prepared of one hundred pounds of soda ash and one hundred pounds of resin, is added. The cover is replaced, and the charge boiled for twelve hours, after which the soap-ley is withdrawn, the kier filled up with cold water as before, a solution of sixty pounds of soda crystals added, and the charge again boiled for three hours. The pieces are now removed to undergo the washing process twice, before being wound into the bleaching solution of chloroxide of calcium, where they remain a few hours; hence they pass through water, then receive a scouring in weak hydrochloric acid, and pass twice through the washing-machine.

Pieces which have not been treated with solution of chloroxide of calcium, are equally as well adapted for dyeing purposes; and the treatment with bleaching liquor may therefore be dispensed with for the greater part of the pieces.

The first scouring with soda crystals is intended to remove traces of acid, and most of the resinous matter, to prepare and aid the action of the resin-soap.

The second boiling with soda crystals is to remove the remainder of resinous substances, and also to free the fibre from adhering rosin-soap.

This method of giving two scourings with sugar-lime offers the great advantage over those methods, where only one scouring with a comparatively strong ley of lime is employed, of weakening the fibre in a less degree.

ANTICHLORINE.—The property of cotton and other woody fibre to condense gases and colors on its surface by a peculiar physical attraction, is well understood. This action, which it has in common with all solid bodies, is so powerful in some instances, that it may even counteract chemical attraction. Cotton and other vegetal fibre which has undergone the bleaching process by chlorine, for instance, has the property of powerfully retaining some chlorine gas. The difficulty of removing this effectually from the bleached fibre is almost insurmountable, requiring a great sacrifice of time, when rapidity is so essential, besides large volumes of water and increased machinery. Now, in order to insure the proper rapidity of the manipulations, either an appreciable amount of chlorine must be left in the bleached fabric or paper-pulp, or else this chlorine must be removed by substances bringing superior chemical affinity into play.

The expedient of only partially removing the chlorine from cotton cloth is certainly in favor of the manufacturer, to the evident disadvantage of the consumer. Chlorine acts gradually on the fibre; it combines with its hydrogen and disorganizes it, renders it brittle, aided by the hydrochloric acid formed. The same is the case with paper-pulp. The action of chlorine left in the bleached pulp is particularly illustrated by the paper manufactured in France soon after the introduction of chloroxide of calcium into the paper-mills. The paper, on running over the hot drying rollers of the machine, becomes brittle; the books printed on it gradually become full of brown spots, and acquire a uniform brownish tint. Every bookseller is acquainted with the inferiority of the modern printing paper in this respect. This deterioration must be entirely ascribed to the action of free chlorine, adhering to the fibre. It is not the paper alone that suffers; the type, too, with which it comes in contact, is affected in proportion to the amount of chlorine left in the paper. It is well to direct the attention of paper-makers and printers to this point, and so furnish them with a ready explanation of the rapid deterioration of the paper and type, and to draw their attention to those chemical agents which may be employed with advantage for counteracting these evils. Agents of this description have been introduced to the public under the general designation of *antichlorine*.

Carbonate of soda or ammonia was first proposed as an antidote for chlorine; but though the latter gas decomposes soda or ammonia in concentrated solutions, the effect in very dilute fluids is very insignificant, and requires the aid of heat. Sulphide of calcium was next introduced; but its property of being decomposed by carbonic acid, with evolution of the fetid sulphide of hydrogen gas, and the black precipitate which it produces with any salt of iron or copper which may be present in the pulp by accident, preclude the use of this salt. Protochloride of tin—tin salt—and a mixture of protosulphate of iron and salt, have the disadvantage of introducing metallic salts into the pulp, which are about as objectionable as chlorine itself. Hyposulphite of soda is somewhat expensive, and precipitates sulphur when brought in contact with chlorine or hydrochloric acid, the sulphur giving a yellowish tint to the paper. Recently a patent was taken out by Roth and Lea of Philadelphia, for the use of a solution of sulphite of soda as an antichlorine. Sulphurous acid and its salts are indisputably the most economical, besides being the most efficient chemical compounds for removing free chlorine. Sulphurous acid alone, however, cannot be employed for the purpose in question, on account of being converted by chlorine into sulphuric acid, which has a detrimental action on woody fibre. The sulphite of soda answers, therefore, all practical purposes, as far as its chemical action is concerned; it is, however, still liable to the objection of difficult transportation in its fluid state, in which it must be sold for reasons of economy, entailing additional expense on the consumer for water-tight casks and freight of a valueless substance—water. These considerations, which oppose a more general application of the sulphite of soda, have induced Professor Horsford to make the use of the cheap sulphite of lime or *antichloride of lime*, the subject of a patent for England and America.

It may appear on first consideration that neutral sulphite of lime, which is very little soluble in water, could have but little effect on the chlorine combined with the fibre; but the fact that hydrochloric acid dissolves neutral sulphite of lime with formation of soluble bisulphite of lime, will readily explain its action. Now hydrochloric acid is invariably generated whenever chlorine gas acts as a decoloring agent on organic substances.

It is the hydrochloric acid thus generated which dissolves the neutral sulphite of lime. Contact with chlorine converts the sulphite into sulphate of lime, which goes to increase the weight of the paper, and practically saves to the manufacturer nearly or quite the whole cost of the sulphite of lime. The article is prepared by agitating milk of lime by means of revolving paddles in a long close box, with fumes of burning sulphur, until the reaction is neutral or acid. It is then drained and air-dried, and packed in casks for transportation.

In connection with the formula given at page 324, column 2, it deserves to be stated that, instead of taking the protosulphate of iron—$FeO\,SO_3$—for the preparation of sulphurous acid, it is more advantageous to employ the *sesquisulphate of iron*—$Fe_2\,O_3,\ 3\ SO_3$—which is obtained by *roasting* green vitriol in the air, and then adding to it half as much more sulphuric acid as it already contains, and evaporating the resulting pasty mass to dryness. One hundred and ninety-eight parts of the dry sesquisulphate of iron are now mixed with eighty parts of sulphur, and heated, whereby one hundred and ninety-two parts of dry sulphurous acid gas are obtained:—

$$\underbrace{Fe_2\,O_3,\ 3\,SO_3}_{\text{Sesquisulphate of iron.}} + \underbrace{5\,S}_{\text{Sulphur.}} = \underbrace{2(Fe\,S)}_{\text{Sulphide of iron.}} + \underbrace{6\,(SO_2).}_{\text{Sulphurous acid.}}$$

while one hundred and ninety-eight parts of the *protosulphate of iron* will only yield one hundred and sixty-nine parts of sulphurous acid.—H.

Bleaching Powder.—At page 328, immediately preceding the formula at foot of column 1, it is stated that the chlorine employed in the experiments was prepared by adding hydrochloric acid to chlorate of potassa. But Böttger found that the gas thus obtained contained $Cl\,O_3$. It is to be presumed that the mixed gases were passed through sufficient water, and at a rate sufficiently slow to permit the entire absorption of the $Cl\,O_3$.—H.

At page 329 a description is given of Fresenius and Will's method for testing the quality of manganese ore. A modification of this method, more simple, and still equally satisfactory for practical purposes, has been proposed by Mohr. It is executed in the following manner:—Three grammes of the finely-powdered and dried manganese ore are mixed in a small glass flask with a little water, and enough sulphuric acid to render the whole mass perfectly fluid. This flask and a porcelain capsule containing about nine grammes of crystallized oxalic acid, are now placed in one scale of the balance, and brought into equilibrium by a basin of sand or small shot. The oxalic acid is now thrown into the flask, where it immediately begins to reduce the binoxide of manganese under evolution of carbonic acid. To accelerate this decomposition, it is good to give the flask a circular horizontal motion, until the evolution of the carbonic acid has ceased, and the mass from black, which it was, has become light-colored. The empty porcelain capsule and the glass flask are now again placed on the balance, and so much weight placed into the capsule as to restore the equilibrium. The weight required to effect this is equal to the weight of a binoxide of manganese in the ore, because one equivalent of binoxide of manganese = 44, when treated with oxalic and sulphuric acids, cause the evolution of two equivalents of carbonic acid = 44; one part by weight of binoxide of manganese is therefore indicated by one part of carbonic acid.

Now, as three grammes of ore have been employed for the above experiment, it follows that the amount of carbonic acid lost, divided by three, indicates the amount of binoxide of manganese in one gramme of the ore; and by multiplying the latter number with one hundred, the per centage of the binoxide is obtained. The error produced by the loss of water in this method does not signify for most practical purposes, but may be remedied by closing the flask with a cork in which a glass tube filled with dry chloride of calcium is fastened. In this case, however, the carbonic acid contained in the flask when the experiment is finished must be removed by suction.—H.

BONE BLACK.—At page 336, eleventh line of first column, it is stated that solutions of sugar are better deprived of their color when alkaline than when acid. This, however, only applies to an alkalinity of sugar sirup produced by *lime*.

Some interesting reflections are suggested by the remark which follows in the same column with reference to the decoloring power of carbon, and M. Bussy's experiment, showing that the reaction is strongly influenced by ordinary chemical forces, instead of being purely mechanical. As the whole universe, with all its diversified phenomena, derives its origin from one *primum movens*, and as all the phenomena connected with matter can therefore only be functions of this creative unit, one may, *a priori*, expect that which is actually observed, namely, the gradual transition and intimate connection of varied effects and causes. Where does inorganic nature cease and life commence? Where stops the action of light, and where does heat begin? Why does magnetism induce electricity? Where do the physical forces—cohesion, repulsion, heat, electropolarity, light and contact force, find a landmark which separates them from what are denominated chemical forces? Every effect must have a cause, and every distinct effect a distinct cause; but it is the defect of the human mind to be slow in distinguishing apparent from real differences. Before NEWTON it would have been undoubtedly considered good logic to conclude, that the force which made the apple *fall* was different from that which kept the earth *steady*. Thus it comes that all definitions of isolated systems fail, and undergo continual amputation and restoration with every progress of science—now hobbling on one bandaged leg, now on another—showing that nature abhors, if not the vacuum, at least systems and definitions; and it teaches that there is no gap in its mechanism, no wheel or spring wanting in its clockwork; in fine, there is no interruption in its development from a single cause or *animus* to its utmost complicity, which is observed in the perfection of organic existence. A disruption in the continuity of effects in the economy of nature would be equal to the interruption of an electric wire between two telegraph stations; because in that case the intelligent cause on one station could no more produce an intelligent effect on the other, in consequence of an apparently insignificant accident. The forces as connected with the phenomena of matter, are in the same predicament. There can be no *real* difference in the so-called forces, because such a difference would constitute a *real* gap; it would stamp the force as an individual, producing an individual effect, so that all the infinitely different effects observed must be ascribed to infinitely different forces.

The attraction of coloring matter by charcoal is denominated mechanical, while the attraction of sulphuric acid by baryta is classed with chemical effects. But animal charcoal does not only attract coloring matter; it also decomposes metallic salts, and fixes their base by that same power of retention. Now it is known that chemical combinations and decompositions are produced by differences in intensity of one only chemical attractive force called affinity. It is evident that the same force is inherent in animal charcoal. This view is corroborated by the fact that animal charcoal absorbs different compounds in different but determined quantities. NIEPCE has shown that iodine and chlorine gas are condensed by the inked portion of printed paper, while the white portion of the paper does not retain any of the gases. Charcoal absorbs heat and light most readily. It condenses electricity on its surface, and thereby acts as a non-conductor, the same as glass, which is only an isolator in consequence of its great attraction for electricity. Metallic charcoal loses, with its power of attracting colors and gases, also the power of attracting electricity, which latter now passes through without hindrance, as through other conductors. Ordinary charcoal condenses gases, and frequently causes chemical combinations. This substance, then, shows the gradual development of chemical effects by physical forces. The effect of animal charcoal depends entirely upon its porosity and the extent of its carbonaceous surface, and is directly proportional to it; and it may therefore be presumed that if the surface of charcoal could be indefinitely increased by solution in water, it would produce all the powerful chemical phenomena of cyanogen or ozone.

If one moves on a step further, binoxide of tin presents itself, a substance already more pronounced in its chemical character than charcoal. Still it is inclined to combine equally as well with bases as with acids, showing a transition character. Now, if pumice be soaked in a solution of bichloride of tin, and then dipped into a solution of carbonate of soda, the pumice acquires all the properties of animal charcoal. Very porous pumice, finely-divided silica, cotton fibre—all these show signs of chemical power depending on their extent of surface; and it may well be supposed that this chemical power would be more prominent, could they be obtained in the fluid state. Silicic acid, which is as inert as charcoal at the ordinary temperature, drives out the powerful sulphuric acid from its combinations at a temperature nearer its own melting point.

Another phenomenon is also connected with the action of animal charcoal, namely, that of endosmosis. It has been shown, as subsequently stated in the text, that a colored sugar solution containing, besides water, some salts, does not pass unchanged through animal charcoal. Pure water is the first to pass through, then comes water with salts, then sugar, and lastly, the color. From this one concludes that animal charcoal has the greatest affinity for coloring matter, less for sugar solution—because the latter is replaced by the former—still less for salt solution, and least of all for water. Could, therefore, a thin diaphragm be constructed of animal charcoal, one would observe the endosmosis to take place from a salt solution into water, and from a solution of sugar into salt, and from a solution of coloring matter into water, salt, and sugar; that is, of such tinctorial matter as has the greater affinity for animal charcoal. Thus a certain molecular attraction in animal charcoal may produce effects ascribed to a multiplicity of forces, as mechanical force—adhesion, endosmotic force, catalytic force; and chemical force—affinity. Would it not be more rational to consider all these as mere functions of the same molecular tendency the intensity of which alone gives rise to variable effects, the same as is observed in sound, electricity, and light?—H.

CORRENWINDER assumes that the decoloring effect of animal charcoal is correlative to its absorbing power for lime; and on this supposition he bases the following method for determining the commercial value of bone black:—A solution of sugarate of lime is prepared, containing, say, twenty grammes of lime in one thousand cubic centimetres fluid, which are neutralized by one thousand cubic centimetres of a standard solution of sulphuric acid, so that fifty cubic centimetres of the acid solution indicate one gramme lime.

The samples of the bone black are now rendered of a uniform condition, by passing them separately through the same sieve, after having removed the fine dust by a paper fan. Fifty grammes of each sample are placed each in a glass flask. In each glass flask one hundred cubic centimetres of the solution of sugarate of lime are added to the bone black, and the whole allowed to digest for an hour. After this the fluid of each flask is filtered separately, and fifty cubic centimetres of the filtrate liquor are tested for the amount of lime with the standard solution of sulphuric acid. The more lime there is absorbed by the bone black, the less sulphuric acid will be required to neutralize the filtered liquor; and that liquor which requires least acid for neutralization, must have been in contact with the most valuable sample of bone black, so that the value of the animal charcoal increases directly as the amount of standard acid required for neutralization decreases.—H.

BORACIC ACID.—At page 342, it is stated that boracic acid scarcely reddens vegetal blues, and renders turmeric brown, like an alkali. This reaction affords an easy means of detecting boracic acid in its combinations, by adding to it a little hydrochloric acid; after which dip into the fluid a piece of turmeric paper, and then dry it. If a trace of the acid was present, the paper will have a brown stain after drying.—H.

BREAD.—Insert at foot of column 1, page 377, Vol. I.—The frequent failure of the grain crops, and the scarcity of grain induced by some other accidental causes, has drawn the attention of chemists to the process of bread-baking, either with a view to discover some substitute for wheat flour, or else to find the means for rendering the whole of the nutritive principles of the cereals available for consumption. The latter direction has already furnished valuable results. It is known that the bran separated from flour contains a comparatively large proportion of nitrogenized substance, namely, that constituent of the flour which contributes most to nutrition. Until quite recently the bran was lost to the nutrition of man. Now, however, it has been shown that this nitrogenized substance may be extracted from the bran without much trouble and expense, so as to obtain the whole of its valuable matter. This process, recommended by a number of chemists, was ultimately patented in France by a Mrs. DURUT. The manipulation is carried out in the following manner:—Bran is mixed up with boiling water in a kettle over a moderate fire, so that the mixture has a semifluid consistency. The mixture is now heated carefully until the bran loses its raw smell—not till it is cooked; it is then transferred into bags and pressed. The pressed cake is treated once more in the same manner, mixing it with water, allowing to boil for a short time, and pressing. The fluid obtained by this second operation is used, instead of pure water, for a fresh portion of bran. By the first pressing a sirupy juice is obtained, completely saturated with gluten, and which is destined to replace the pure water in the process of bread-baking; thus gaining for the bread a large proportion of valuable nutriment entirely lost before. The economy of this process is thus stated:—A bag of flour of the average weight of three hundred and twelve pounds, made into bread with water in the usual manner, yields on an average one hundred and four loaves of four pounds each. A bag of flour of the same weight, made into bread with the extract of bran, yields one hundred and thirty loaves of four pounds each, or a clear gain of twenty-six loaves over the old process. Twenty-five per cent. increase in the yield of bread from the same amount of flour is a fact the importance of which cannot easily be exaggerated.

BROMINE.—The process detailed at pages 393, 394, for the separation of bromine and chlorine, may with advantage be modified in the following manner:—Precipitate the solution containing chlorine and bromine with nitrate of silver; wash, dry, and heat the precipitate to a state of semi-fusion in a weighed porcelain capsule. Weigh the capsule with the silver precipitate, then reduce the latter with the aid of zinc and sulphuric acid in excess. Wash out the reduced silver, ignite, and weigh it. If one supposes the weight of the chloride and bromide of silver to be a, and that of the metallic silver obtained from it by reduction with zinc to be b, and the amount of chlorine to be x, the amount of bromine will be $a - b - x = y$. From this we conclude:—

$$\frac{107{\cdot}97x}{35{\cdot}46} + \frac{107{\cdot}97y}{79{\cdot}97} = \text{C.},$$

from which is deduced:

$$x = 1{\cdot}38674\text{C} - 0{\cdot}79667a$$

That is, multiply the weight of the reduced silver by 1.38674, and deduct from the result the product obtained by multiplying the weight of the chloride and bromide of silver with 0·79667, and the result will be the amount of chlorine in the mixture. By substracting the weight of the chlorine plus that of metallic silver from the weight of the chloride and bromide of silver, the amount of bromine is obtained.—H.

CANDLE.—Read, in connection with the processes described at pages 430, 431:—The operations of saponification of the fat, and decomposition of the lime-soap by sulphuric acid, have been hitherto effected in open vessels, under the ordinary pressure of the atmosphere. An improvement on this plan has been recently proposed by M. DELAPCHIER, of Besançon, who substitutes close vessels in order to saponify the fat. Wash and decompose the lime-soap under a pressure of about twenty-two pounds to the square inch, by which the operations are considerably facilitated, and their duration shortened. The products by this process are said to be superior to those obtained in open vessels, and a considerable economy of fluid is effected. The apparatus consists essentially of a horizontal boiler, with a man-hole and two safety valves at the top. The heat is furnished by a large steam-pipe, running in a depression along the bottom of the boiler. The pipe is perforated with numerous holes to distribute the heat more uniformly. A horizontal iron shaft, which passes through stuffing boxes in the heads of the boiler, carries an agitator, the transversal ribs of which nearly touch the circumference of the boiler. A large pulley at one end of the shaft receives its motion from a suitable motor. The materials are charged through the man-hole, and at the end of the operation withdrawn by a large valve at the bottom of the boiler.—H.

CAOUTCHOUC.—The qualities of sulphurized caoutchouc are described in column 2, page 448, vol. 1 :—Allowing the chemical composition of caoutchouc to be $C_8\ H_7$, the formula of the best vulcanized rubber car-springs is found to be very near—

$$S + 24\ R + 3\ PbO + 3\ CaO,\ CO_2;$$

R signifying one equivalent of rubber$=C_8\ H_7$. It rubber was represented by $C_{64}\ H_{56}$—or eight times its present equivalent—the vulcanized car-springs would have the compact formula :—

$$S + 3\ (R\ PbO\ CaO\ CO_2.)$$

H.

CIDER.—At page 475, middle of column 2, it is stated that in warm seasons it is still a desideratum to discover some means of checking a too rapid fermentation of cider. The process for the prevention of fermentation in saccharine solutions, denominated *mutismè* by the French, may be very easily applied for effecting this purpose. By adding to fermenting powder from one six hundredth to one thousandth of neutral sulphite of lime, or of bisulphite of soda, the fermentation may be reduced to a minimum, or entirely checked.

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CHEMISTRY,

THEORETICAL, PRACTICAL, AND ANALYTICAL,

AS APPLIED AND RELATING TO THE

ARTS AND MANUFACTURES.

BY

DR. SHERIDAN MUSPRATT, F.R.S.E., M.R.I.A.,
Founder and Principal of the College of Chemistry, Liverpool;
Honorary Fellow of the New York College of Pharmacy; Fellow of the Royal Agricultural Society of England;
Membre de la Société D'Encouragement; Membre do l'Académie Nationale de France;
Author of Outlines of Analysis; Chemistry of Vegetation; Influence of Chemistry; and Editor of Muspratt's Plattner on the Blowpipe;
&c. &c. &c.

VOL. I.

ACE — ETH

LONDON:
WILLIAM MACKENZIE,
22 PATERNOSTER ROW; HOWARD STREET, GLASGOW;
SOUTH BRIDGE, EDINBURGH.

PRINTED BY WILLIAM MACKENZIE, 45 & 47 HOWARD STREET, GLASGOW.

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VOL. II.

FUEL — ZINC

A.D. 1803.

LONDON:
WILLIAM MACKENZIE,
22 PATERNOSTER ROW; HOWARD STREET, GLASGOW;
SOUTH BRIDGE, EDINBURGH.

Printed by William Mackenzie, 45 & 47 Howard Street, Glasgow.

PREFACE.

The Editor, in congratulating himself and his readers that his arduous but not unpleasant labors are at length brought to a close, begs to acknowledge most gratefully the cordial support which he has received from the conductors of the periodical press, and the numerous favorable testimonies, not only from the most eminent scientific men and manufacturing chemists, but also from non-professional readers and subscribers generally, by which he has been sustained and encouraged. It is only those who have been actually engaged in a work of this kind, that are able to conceive the vast amount of labor which it involves, and the difficulty of realizing in detail the ideal standard which an author usually proposes to himself in commencing such an undertaking; especially one that has to extend over a period of several years.

With reference to the present Work, the Editor is well aware that it labors under many imperfections, but he is conscious also that he has spared no pains to render it as extensively useful as possible; and he thinks he may say with entire confidence and without presumption, that in no other work hitherto published will be found so complete an exposition of the state of the chemical manufactures, with the latest and most improved processes. He regrets exceedingly that in aiming to embrace the whole of these, so far as they appeared to him of any practical value, and in wishing to avail himself of the numerous details, articles, *et cetera*, so kindly furnished to him by his valuable and talented assistant, Mr. Murphy, Mr. George Blair of Glasgow, and other scientific friends, and in many instances by gentlemen immediately engaged in or connected with the different manufactures, he has found it necessary to extend the Work somewhat beyond the limits originally assigned. It may even appear to the general reader that in some cases he has described particular processes with too much minuteness; but those who are really desirous of useful practical information on any of the subjects discussed, will find in this very minuteness of detail the most valuable feature of the Work. Many of the articles might have been considerably extended, but few of them, if any, could have been much abridged, without omitting facts the importance of which the reader will be best able to appreciate when he consults the book for his practical guidance.

SHERIDAN MUSPRATT, M.D., &c.,
PROFESSOR OF CHEMISTRY.